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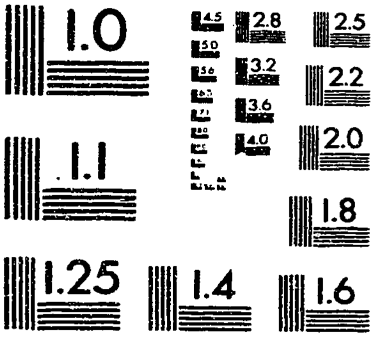

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INSTRUCTIONAL DEVICES: DEVELOPMENT, LEARNING THEORIES, AND DEPLOYMENT

BY

GEORGE H. BUCK ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Reseach for acceptance, a thesis entitled, INSTRUCTIONAL DEVICES: DEVELOPMENT, LEARNING THEORIES, AND DEPLOYMENT, submitted by GEORGE H. BUCK in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

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Im Gedenken an eine große Institution

ABSTRACT

This work investigates several classes and types of instructional devices from a perspective of the explicit or implicit learning theories that they embody. Definitions of terms are provided. The consideration of instructional devices is presented primarily in a chronological fashion, beginning with examples of ancient innovations and concluding with descriptions and discussions of modern techniques of simulation and instruction by computer. The approach used is not *historical* in the sense of a chronicle, since this work is not intended to be a catalogue of instructional devices. Representative examples are described and discussed to elaborate prevalent theories and/or to exemplify the type of instructional devices used at a particular time.

One theory of learning and instruction that appears to recur throughout history is that of presenting information in a hierarchical fashion, beginning with the concrete and ending with abstract representations. In most instances, the transition from the concrete to the abstract, and *vice versa*, is facilitated by using particular instructional devices. In a similar vein, this work uses illustrative materials to facilitate the comprehension of the particular instructional devices discussed and their inherent theories of learning and instruction.

Factors identifiable as affecting the development, deployment and continued use of instructional devices are noted and discussed. The factors considered extend beyond those related purely to theory and pedagogy. A development and implementation model, represented iconically, and applicable to any instructional device is presented in the concluding chapter. This model coalesces the factors affecting the development and deployment of instructional devices, identified in the previous chapters, into a coherent system that explains how and why a particular instructional device may gain widespread use or be abandoned in spite of its apparent utility.

This work not only explains where we have come from in respect to the development and use of instructional devices, but it also offers some guidelines that may be helpful when applied to current and future instructional devices. These guidelines are intended to reduce the likelihood of new instructional devices being rejected through ignorance of factors that may not be apparent readily, but which still impinge upon instructional devices.

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The author regrets any errors and omissions, and apologizes for them .

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Chapter I

Introduction and review of literature

Introduction

Instructional devices of one sort or another are used in almost all contemporary instructional settings. The apparatus may be as simple as a blackboard or as complex as a computer to duplicate the actions of either another machine or some aspect of human behavior. In most instances, the way instructional devices are used is determined either by an implicit and unstated notion about the ways in which human beings learn, or by the principles of a learning theory or a theory of pedagogy that are stated explicitly. With the introduction of new devices and new theories of learning and instruction usually come claims that the new apparatus and approaches will result in either a radical change in the way in which instruction is provided, or that the efficiency and the efficacy of instruction and student learning will be increased markedly (Clark, 1983). An example of such a claim can be found in Bork (1981) who states,

> We are at the brink of a major revolution in ways of learning. Very few people - not even professional educators - understand what is about to happen. The revolution will occur within the next 25 years and will affect our educational system at all levels. (p. 1)

Bork is not alone in making such predictions about the impact of computer technology on education. Suppes (1966) for example, states "One can predict that in a few more years millions of school-children will have access to what Philip of Macedon's son Alexander enjoyed as a royal prerogative: the personal services of a tutor as well-informed and responsive as Aristotle" (p. 207).

Predictions of this sort are not a new phenomenon. In 1913, Thomas Edison, the inventor of one of the first motion picture systems stated, "Books will soon be obsolete in schools. Scholars will soon be instructed through the eye. It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed in ten years" (cited in Saettler, 1968, p. 98). Similar predictions about how their devices and methods will alter education radically have been made by others such as Pressey (1926; 1927; 1932) and Skinner (1954; 1984).

While it might at first appear that the inaccuracy of such predictions implies that most instructional devices are destined to fail, or that a positivistic attitude about the development of instructional devices is inappropriate, it is important to consider that some instructional devices and theories of learning have become integral components of most contemporary instructional settings. To gain greater insight into some of the factors that determine whether an instructional device and its inherent learning theory will succeed or fail in practice might be beneficial both to educators and to those whom they educate. Teleological predictions of the sort quoted in the previous paragraphs do not appear to consider many key factors that seem to influence the development of instructional devices and learning theories. For example, was the reason why the motion picture failed to become the primary means of instruction by 1923, as Edison predicted, the result of poor technology, or was the pedagogical premise of using motion pictures for instruction faulty? Perhaps neither factor contributed to this failure. Another possibility is that Edison and/or others considered the technology of motion pictures to be a *solution looking for a problem.* By applying motion pictures to the field of education, a potential market that had not yet been tapped by such technology, it may have been hoped that teaching might be improved and that Edison's company might also increase its profits.

To gain some knowledge of which factors did affect the development and deployment of instructional devices, it is necessary to consider their development within the context of a long time frame as well as within the context of the learning theories that they embody. Several purposes are served by this approach. First, a more objective view is possible, since there is now little or no vested interest in devices invented in earlier periods. Second, it is possible to trace the development of a particular instructional device from its inception through to its ultimate fate. Third, it may be possible to ascertain whether there is or has been a chronological development of instructional devices and/or learning theories. Fourth, a broader perspective may reveal whether or not some recurring claims that pervade the literature are either accurate or erroneous. Fifth, any apparent factors or patterns of development discovered may be applied to current devices and situations to enable better predictions about their usefulness and their possible efficacy in particular educational settings.

Delimitations and limitations

While this work describes and analyzes the development of instructional devices and the learning theories that they embody, the major emphasis is the consideration of devices that are intended to provide interactive instruction largely independent of a teacher; teaching machines. A subsequent section of this chapter provides operational definitions of some key terms used throughout this work. Other devices that serve instructional purposes, but which are used as adjuncts to instruction by the teacher (teaching aids) such as blackboards and the radio are considered, but only within the context of how their development and deployment have had an effect upon the development and the deployment of teaching machines. Devices such as computers are not considered to be representative of one particular type of instructional device exclusively. Such devices are categorized depending upon how they are configured and for what particular applications they are intended. It is not the purpose of this work to provide an exhaustive historical catalogue of instructional devices through the ages. What is intended is to describe the development of particular instructional devices within the context of the learning theories they embody, and to analyze their development so that factors affecting their development, deployment and their inherent learning theories may be discernible. The concluding chapter incorporates discernible factors into a development and deployment model that may be applied to contemporary endeavors.

This work considers instructional devices from ancient times through the present. The focus begins with a broad geographical base and gradually narrows the focus to specific geo-political areas as the time line approaches the present. Other geo-political areas are not excluded, however, when it is established that an important development in such locations has had a major impact upon learning theory or on the development or use of instructional devices. While the general development of the work is chronological, there are particular chapters that consider specific types or classes of instructional devices out of sequence with chapters that describe and analyze general classes of instructional devices.

Although it might seem from the foregoing that this work is primarily an historical treatment, the main thrust is an analysis of classes of instructional devices and their inherent learning theories rather than an annotated chronicle or catalogue of the development of instructional devices *per se*. It is for this reason that representative examples of devices will be provided instead of a listing of all known instructional devices of a particular type.

Many terms are used in other works to refer to particular classes of instructional devices. Such terms include: *teaching machines, learning machines, learning devices, auto-instructional devices, learning aids,* and *teaching aids.* While some of these terms have been defined according to particular variants of a class of instructional device (Porter, 1957, for example) most of these terms are used by different authors to describe either identical or similar apparatus (Fry, Bryan & Rigney, 1960). To provide clarity and to reduce the likelihood of confusion, a taxonomy of operational definitions of general classes of instructional devices is provided.

Operational definitions

Definitions of terms that are used frequently in this work are necessary, since these terms have been defined in many different ways in the past. Garner (1966) for example, cites no fewer than seven different definitions of the term *teaching machine* (pp. 29-30). In attempting to diminish the ambiguity of the term, others have created new terms to refer to the same thing. Foltz (1961) uses the term *self-instructional device* instead of teaching machine, "Since the devices themselves do not teach, but are used to hold programs so that the student may teach himself" (p. 2). Porter (1957) prefers the term *teaching devices*, since he also refers to apparatus used by teachers as adjuncts to instruction. Eckstrand, Rockway, Kopstein and Morgan (1961) use three terms synonymously to describe one type of apparatus. The terms are *teaching machines, automated training devices* and *self-instructional devices* (p. 1). Quackenbush (1961) variously uses *teaching machines* and *auto-instructional devices*. In spite of the creation of new terms, *teaching machine* continues to be used extensively in the literature (Skinner, 1984, for example). Finn and Perrin (1962) state, "the term, teaching machine, is short and succinct and, particularly in the popular press, interesting, provocative and exciting... it is a moot point, we feel, whether it can ever be expunged from the vocabulary of psychologist, educator and reporter" (p. 15). Given the prevalent use of the term *teaching machine*, it is appropriate to clarify what it refers to in this study.

Teaching machines

A teaching machine may be defined as a mechanical, pneumatic, electrical, electromechanical or electronic device which, upon some sort of manipulation (input) by the user, performs a transformation of the input and then provides some recognizable form of instructive feedback. Forms that teaching machines may take include: the simulation of a realistic condition, a dangerous condition or a situation not readily observable by the user; the tangible manifestation of a theory or a philosophy; the presentation of questions or information followed by questions, with provisions for response and analysis of the response. By this definition, therefore, books, chalkboards, globes and similar materials are not teaching machines. Computers, however, may be configured to perform as teaching machines. Examples are dedicated personal devices such as *Speak & Spell*, and software-driven computer-assisted instruction systems such as *Programmed Logic for Automatic Teaching Operations (PLATO).*

Teaching aids

Teaching aids may be considered to be those items which do not fit the above definition, but which are used primarily as adjuncts in pedagogy or training. Diagrams, books and blackboards may be considered teaching aids, therefore. The following example may make things clearer. A diagram of the solar system is not mechanical, nor can it accept any form of input which will result in it performing a transformation and presenting instructive feedback. It is not a teaching machine. The diagram may be used by a teacher in a lesson to illustrate the relative position of the planets. In this instance, it is being used as a teaching aid.

Necessary tools

Necessary tools comprise those instruments or devices which are essential for a particular activity to be accomplished. A violin, for example, is a necessary tool for violin playing. Similarly, a compass or a circle template is a necessary tool for the drawing of true circles in a demonstration of geometry. It is possible to consider necessary tools as teaching aids if they are used for instructive purposes in a subject for which they are not necessary. An example is the use of the violin to demonstrate the principles of harmonics to a physics class. While a violin may illustrate harmonics adequately, it is possible to use other instruments and apparatus for this purpose. In this instance the violin is a teaching aid, not a necessary tool.

Instructional devices/ instructional apparatus

These terms refer to all devices or apparatus that are used for instruction generally, when it is not necessary to distinguish between teaching machines, teaching aids or necessary tools.

Programmed instruction/ programmed learning

While it may be argued that all forms of instruction follow a particular program or logical sequence, these terms refer synonymously to those programs of study that have been prepared following the basic tenets of behavioristic learning theory. A topic or a specific task is reduced into small, discrete elements. Through some medium, either a special book or a machine, the discrete elements are presented to the student in some logical sequence, usually in a hierarchic order (Foltz, 1961). The particular sequence is dependent upon the nature of the subject matter, the particular learning theory that the designer follows and the medium of presentation. The presentation of information requires an interaction by the student, so another element of programmed instruction is frequent student responses to the elements of instruction. Another aspect of programmed instruction is *individualized instruction*, where each learner is permitted to proceed through the material at his/her own pace (Foltz; Austwick, 1964). Several different program configurations have been developed for presenting material according to the principles of programmed instruction. They will be defined and explained now.

Linear programs

A linear program is a sequence of instruction that proceeds toward a specified instructional goal without provision for deviating from a singular path towards the goal. With this method, all of the learners are exposed to all of the elements or *frames* of the program, whether they need to be exposed to them or not. Figure 1 is a schematic representation of a portion of a linear program.

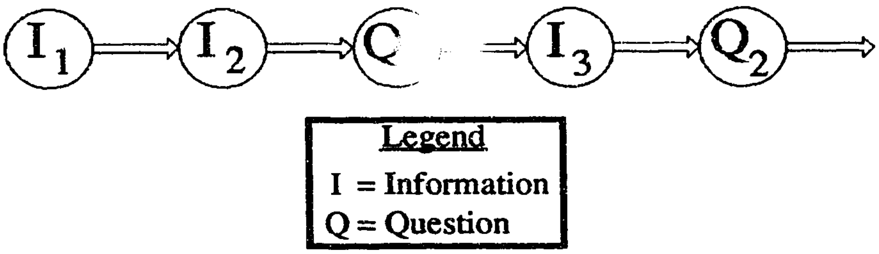


Figure 1. Schematic representation of a linear program

Modified linear program

This type of program is intended to respond to learner differences and/or to differences in previous knowledge of the topic. With this design, learners may be permitted to skip particular elements or frames of the program, contingent upon responding successfully to a test question. If the response is incorrect, the student is shown the next frames in the sequence, which are intended to explain the material further. Those who respond correctly skip the additional frames and proceed to new material. Figure 2 shows the progression through a typical modified linear program, represented schematically.

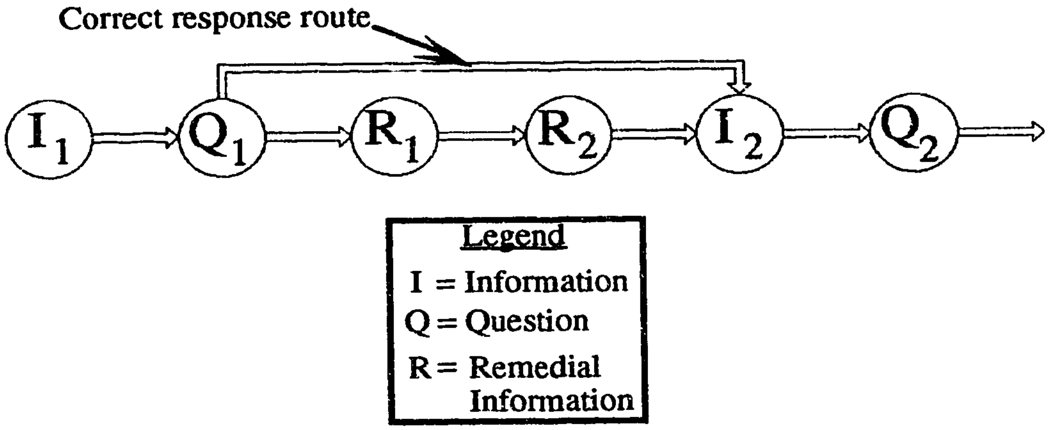


Figure 2. Schematic representation of a modified linear program

Branching program

A limitation of both linear and modified linear programs is that they cannot undertake much analysis of student errors. With branching programs, once an error is made, additional test frames are provided to analyze the nature of the error further. Once the probable cause of the error is isolated, the student is presented with or directed to remedial frames that are intended to correct the assumed misunderstanding. Once the sequence of remedial frames is completed successfully, the student is returned to the main program sequence.

This type of programming is also known as *intrinsic programming*, a method developed by Norman Crowder. Crowder (1960) specifies where in the main program the student returns after completing the remedial frames. The student may be returned to the same position in the program where the remedial frames began, or the student may be returned to a point either before or after the initial point of deviation. When the point of return is before the original point of departure, Crowder (1960) calls this a *wash-back* program. A *wash-ahead* program is when the student is returned to the main program several frames ahead of the original point of departure. Figure 3 shows, in schematic form, an example of a branching program with different points of return from the remedial frames.

Computer-assisted instruction

Computer-assisted instruction (CAI), like the term *teaching machine*, is used widely to refer to a variety of methods of instructing through the use of computers. Different

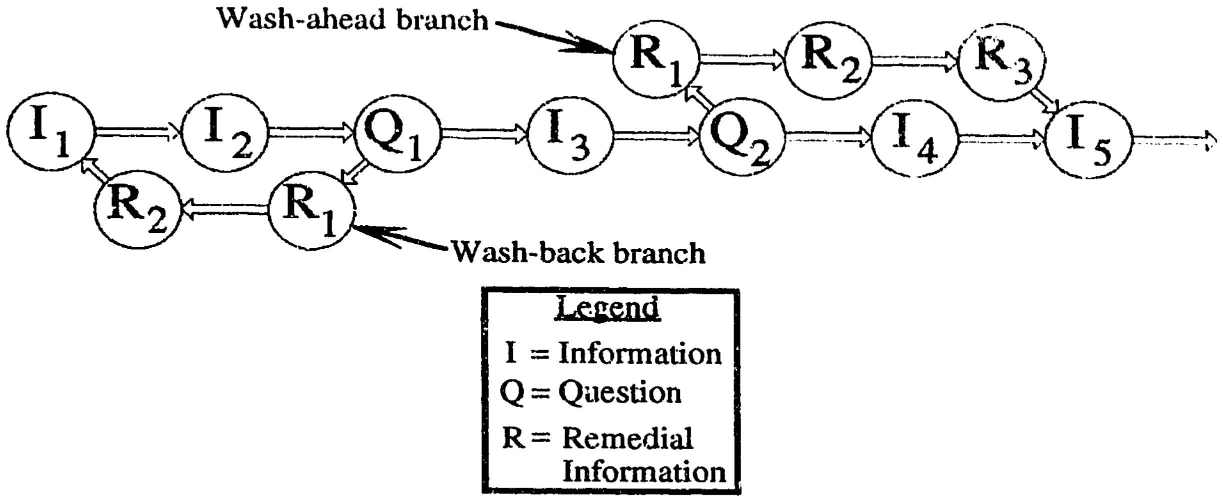


Figure 3. Schematic representation of a branching program

names have been devised to refer to the subject generally and to refer to specific varieties of this type of instruction. Some of the different names include *computer-aided instruction, computer-aided education (CAE), computer-assisted learning (CAL), computer-assisted training (CAT), computer-based education (CBE), computer-based instruction (CBI), computer-based learning (CBL), computer-based training (CBT), computer-managed instruction (CMI) and computer-managed learning (CML).* While each of these terms may have a specific meaning within a particular context, for the purposes of this study the term *computer-assisted instruction (CAI)* will be used generally to refer to instruction presented by computers. Other related terms will be used only when necessary.

While some computers have been set-up to perform as teaching machines or as vehicles for programmed instruction (Bitzer, Braunfeld & Lichtenberger, 1961; Hunka, 1977; Niemiec & Walberg, 1989) one must bear in mind that most computers and computer programs for educational purposes were not designed either within the constraints of programmed instruction, or within the limitations imposed by mechanical teaching machines. Hunka (1968) states, "the capabilities of the computer for handling the strategies which they [educators who use programmed instruction] have been so prone to use, such as a 'linear program' or a 'branching program', far exceed what is capable in a programmed text or mechanical teaching machine" (p. 6).

Additional terms that are specific to particular instructional devices or to particular chapters, will be defined as they are encountered.

Review of literature

Similar works

Although instructional devices have been used for many years in educational settings, there appear to be few works concerned with describing and analyzing the development of such apparatus. The number of such works that also relate their analyses and descriptions to various theories of learning are fewer still. Of the known works concerned with this subject, none is extensive, and most are written from an Americanocentric perspective. One of the earliest accounts is an article by Mellan (1936). It consists of an extensive listing of United States patent numbers and titles of various instructional devices. Apart from the listings, no further information or elaboration is provided. There is no indication, for example, that similar devices were produced in other countries, so it is possible for one to assume that the devices were invented by Americans only. An investigation of a sample of the patents listed, reveals that some devices originated in other countries and were patented subsequently in the United States (United States Patents, Numbers: 198,749, July 24, 1876; 281,770, July 24, 1883; 501,136, July 11, 1893; 1,103,369, July 14, 1914).

A more extensive treatment by Anderson (1962) describes the development of several aspects of education in the United States between 1650 and 1900. The development of school architecture and school furniture are discussed as well as the development of instructional apparatus. The forward, by James Finn, disclaims that the work is intended as a definitive account, and it also indicates that the author is an historian rather than an educator (p. iii). The work is, therefore, largely a chronicle with little analysis of the learning theories inherent in the various devices described. A major limitation of Anderson (1962) is that the work is concerned with American developments solely, without placing such developments in context. It may be assumed, therefore, that the ideas for many instructional devices, or even the concept of educational innovation in general, are American in origin. Anderson (1962) does cite primary sources mainly to support his points.

British authors wrote a two-volume account (Stewart & McCann, 1967; Stewart, 1968) of the development of innovative educational methods and devices in the United Kingdom from 1750 to 1967. While these works describe many early innovative techniques in detail, recent developments are not discussed as extensively, and the discussion centres on general theories of pedagogy and learning. Little is mentioned of either the teaching machine/programmed instruction movement, or of recent innovations with computers.

One of the most widely cited sources related to the development of instructional devices and their inherent learning theories, is the compendium edited by A. A. Lumsdaine and R. Glaser (1960). As well as containing articles that discuss the status of teaching machines and programmed instruction at that time, the book includes reprints of earlier articles concerned with instructional devices. The article by Mellan (1936) is reproduced and some early articles by Pressey (1926; 1927; 1932). Although Lumsdaine and Glaser (1960) note that portions of the various articles have been edited (p. 32) comparisons between the edited versions and the originals reveal some curious omissions that could alter the meaning of the article from what was intended originally. An example of this phenomenon may be found in the reprint of Pressey (1932).

In the original article (Pressey, 1932) a note mentions the earlier invention of several self-scoring devices by other individuals (p. 669). The reprinted version (in Lumsdaine & Glaser, 1960) omits this note. While it is arguable whether or not knowledge of earlier contributions is as important as knowledge of Pressey's work, it is possible, in view of the editorial omission, that no work along this line was undertaken before Pressey's efforts. Many works that describe the history or the development of teaching machines or instructional devices in general, subsequent to Lumsdaine and Glaser (1960) make this assumption. Examples include Eckstrand, Rockway, Kopstein and Morgan (1961); Morrill (1961); Finn and Perrin (1962); Holland (1962); Austwick (1964); Kay, Dodd and Sime (1968); Saettler (1968); Cleary, Mayes and Packham (1976); Pagliaro (1983); Benjamin (1988); and Heines (1988). Some textbooks have made this assumption as well (Lefrancois, 1988; Hergenhahn, 1988).

To be sure, there are other authors who indicate that Pressey's devices were not the first to be devised for instructional purposes. Such accounts include Cram (1961); Epstein and Epstein (1961); Henry (1961); Stolurow (1961); Deterline (1962); Jonassen (1979); and Saettler (1979). It may at first seem trivial whether Pressey designed the first teaching machine or not, since the field of education no longer uses such machines directly. The matter is actually of great importance, especially if one accepts that Pressey developed the first teaching machine. If Pressey invented the first teaching machine, what reason is there for considering possible developments prior to this time? Such a limited view has the potential for erroneous conclusions, given that teaching machines may have been invented and deployed at a much earlier time. By not being aware of earlier developments, it is not possible to benefit from such earlier experiences.

Newer accounts include an article by Lawson (1973) that describes some historical antecedents he contends to be precursors of some modern teaching machines that operate according to the principles of programmed instruction. Although the Roman educator Quintilian is mentioned (p. 93) his learning theory is not described. Instead, Lawson tries to explain one of Quintilian's instructional devices from the basis of programmed instruction. Lawson claims that Quintilian's device is a teaching machine, but Lawson does not define his terms, and so it is not clear what he means by *teaching machine.*

Although Lawson (1973) mentions the quintain, he attributes its invention to the mediæval period, but does not cite primary evidence in support (p. 94). In explaining the operation of the quintain from the rubric of Skinnerian behaviorism, Lawson misapplies a term. He states, "The negative reinforcement [being struck by the quintain] served as a strong inducement to improve the knight's performance" (p. 94). *Negative reinforcement,* in respect to Skinnerian behaviorism, is the removal of or the escape from any noxious stimulus. This action will, in turn, tend to increase the probability that a particular behavior associated with the noxious stimulus will recur (Skinner, 1953). *Punishment* is what Lawson is actually describing. Skinner (1971) states, "Punishment is designed to remove awkward, dangerous, or otherwise unwanted behavior from a repertoire on the assumption that a person who has been punished is less likely to behave in the same way again" (p. 57). The quintain is described and discussed in Chapters II and III.

Lawson (1973) mentions Mellan (1936) and the titles of some of the patents. Lawson claims that most of the patented devices are probably not teaching machines, because they "do not provide immediate feedback" (p. 94). Lawson admits that he is speculating, however, since he did not examine most of the patents. He states, "To check on the other 300 patents ... requires a substantial investment in time and money" (p. 94). Several patents listed in Mellan (1936) are described and discussed in Chapters IV, V and VI. Lawson (1973) mentions other theorists and educators such as John Locke, Edward Thorndike and Maria Montessori, but extensive descriptions of their learning theories or their instructional devices are not provided.

Another treatment is the one-page article by Geis (1987) who describes the quintain incorrectly and who dismisses all previous instructional apparatus as being, "fragile and jerry-built devices [which] were soon superceded [sic] by computers — Mercedes Benz compared with goat carts" (p. 3). No references are cited in this work.

Pagliaro (1983) describes the history and the development of computer-assisted instruction (CAI) in a linear fashion, starting with Pressey's devices. Pagliaro defends his starting point by stating that, "the early contribution Pressey made by integrating the notions of machines and learning, as well as his introduction of a mastery learning paradigm into his 'teaching machines,' are the major reasons for beginning the overview of the history of CAI with Pressey" (p. 76). This claim is at variance with Pressey and with B. F. Skinner, since both claim that their respective development of instructional devices was independent and singular initially. Pressey (1932) states, "The writer has found from bitter experience that one person alone can accomplish relatively little" (p. 672). Skinner (1983) states that he designed his teaching machines without knowledge of previous developments, "I had not known of Pressey's work" (p. 70). Other works including Niemiec and Walberg (1989) concur with Pagliaro's position and argue that computer-assisted instruction is a direct development from the devices of Pressey and Skinner (p. 263). A similar approach is adopted by Collis and Muir (1984).

More recent accounts include two articles published during 1988. One, by Heines (1988) claims to, "consider the history of the development of learning tools in classroom instruction" (p. 24). Although Heines notes that there were a large number of instructional devices patented in the United States by 1936, none are described, nor are any ancient or mediæval instructional devices. Heines claims that Edward L. Thorndike created the theoretical basis for instructional devices through statements in his 1912 work on education. The first actual device described by Heines (1988) is the apparatus patented by Sidney Pressey in 1926. Most of the other devices invented by Pressey are described as well as the teaching machines invented by B.F. Skinner in the 1950s. Contributions by Norman Crowder and Robert Mager are also mentioned. Like Lawson (1973), Heines (1988) confuses negative reinforcement with punishment. Further analysis of the learning theories inherent in the various devices is minimal, as are descriptions of computer applications to learning and instruction.

The other article is by Benjamin (1988). This account follows the same basic pattern as Heines (1988). Benjamin (1988) does include illustrations of some of the instructional devices patented in the United States and listed by Mellan (1936). Unlike most earlier accounts, Benjamin (1988) does define the terms he uses and he does distinguish between teaching aids and teaching machines. It is unfortunate, but one of the patented devices discussed by Benjamin, a device for teaching spelling devised by Halcyon Skinner in 1866, is misunderstood and is described incorrectly. The impression is given that the device was intended to be a teaching machine rather than a teaching aid, and that the device was a dismal failure as a teaching machine. The apparatus was actually intended to be used by a teacher as a teaching aid (see Chapter V). Benjamin does not consider contributions and developments by individuals in other countries. In describing a teaching aid employing a number of wooden blocks, patented in 1911, Benjamin (1988) claims that the device, "is of special interest to psychology because it is the first teaching aid to cite psychological research as a basis for its design" (p. 704). While it is extremely difficult to say with certainty which teaching aid was the first to be designed from psychological findings, it is important to note that many of Maria Montessori's teaching aids were derived from both formal and informal psychological studies conducted during the nineteenth century (Myers, 1913).

Benjamin (1988) also describes B. F. Skinner's teaching machines as well as some of the developments in the area of computer-assisted instruction. Benjamin notes that most of these ventures failed, and he summarizes that teaching machines, "emerged in the 1920s at the hand of Sidney Pressey" (p. 711). Moreover, Benjamin concludes, "if past behavior is a predictor of future behavior, then it seems unlikely that computers or any other teaching machines will play more than a supporting role in the classroom" (p. 711). The two previous quotes typify why such a limited approach is dangerous. Benjamin's conclusion is based on the assumption that there were no teaching machines used successfully for a long period of time prior to Pressey's developments in the 1920s. The successful and prolonged use of teaching machines in other geo-political areas prior to Pressey's endeavors could invalidate Benjamin's conclusion.

Buck (1989) provides descriptions of possible teaching machines and teaching aids in the ancient world. While the article increases the time frame in which we may consider instructional devices, it does not consider developments beyond the end of the ancient era, except in general terms, so one may not perceive any relevance between ancient devices and current attempts at developing and using instructional devices.

General treatments

Some researchers, such as De Cecco (1964); Saettler (1968); Clark (1983); Cuban (1986); Ellison and Coty (1979); Gagné (1987); and Spencer (1988) consider instructional devices as *media, educational technology* or as *instructional technology*, the study of which comprises a discrete and an independent discipline (Gagné, 1987). Researchers who maintain such views tend to focus on the technology itself rather than the relationship of the particular devices to theories of learning. Limiting one's view in such a way may result in relevant factors being ignored, possibly resulting in the overestimation of the actual pedagogical value of the technology. The quotes of Edison and Bork, cited in a previous section, are examples of this phenomenon. In another example, Clark (1983) states, "The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (p. 445). This statement is wrong in several ways. Firstly, the so-called medium may influence student achievement depending upon what it is intended to do and upon how it is deployed. While a truck delivering groceries does not cause changes in our nutrition directly, it may do so indirectly. Modern trucks are capable of transporting fresh fruit and vegetables quickly to areas where they do not grow, at all times of the year. Ox carts and wagon trains, for example, normally cannot accomplish this because of their slow speed. Using such vehicles will result in the fruit and vegetables becoming spoiled or rotten by the time they reach the destination. The nutrition of the individuals who expect to receive the produce will suffer, therefore. Similarly, instructional devices are not necessarily *vehicles* to deliver instruction. Teaching machines not only present information, but have the capacity to receive input, evaluate it and then provide feedback that is instructive to the user. To be sure, many instructional devices such as the blackboard are used primarily as vehicles to present information. If we consider instructional devices solely as media, then we tend to limit our perspective to the *vehicles* only and not to the information they are capable of conveying, or to the instructional methods or strategies that they embody.

Some authors in the field of instructional technology do attempt to explain the merits of and the use of particular devices in respect to learning theories. In most instances, however, such explanations are limited by comparing the devices to the principles of behaviorism, whether they are appropriate to the particular device or not. Jonassen (1979) for example, criticizes some ancient teaching techniques as being vague in comparison with modern views of programmed instruction. Jonassen states, "The rhetoricians of democratic Athens in 400 B.C., and later the catechumens of the Middle Ages, approached an early counterpart to the small steps, sequential instruction, and question-and-answer pattern of 20th century programmed instruction" (p. 275). While there appear to be some similarities between some ancient teaching methods and the principles of programmed instruction, there is no evidence to show that ancient educators designed their instruction according to any plan similar to modern programmed instruction. By viewing earlier methods and developments as though they are either vehicles or direct precursors of programmed instruction, the actual nature of earlier learning theories and teaching methods are not likely to be understood. It is for this reason that this work is not concerned with what is referred to variously as *educational technology, instructional technology or instructional media.*

Other works

It has been mentioned previously that there has been little work done on an extensive treatment and analysis of the development of instructional devices and their inherent learning theories. It was necessary, therefore, to consult works outside the area of educational psychology, and to also consult works outside the field of education. Examples include: ancient and mediæval works in the original and in translation, letters of patent, books and articles concerned with theories of learning and pedagogy, books and articles concerned with specific devices and with the application of particular theories of learning or strategies of instruction, technical specifications and a survey instrument. Wherever possible, original source material is used rather than secondary material, so as to ensure that errors of transmission and interpretation are kept to a minimum.

A survey instrument was developed for distribution to manufacturers of teaching machines and particular teaching aids. It is reproduced in Appendix A. The instrument was designed and used for two reasons. First, letters sent to companies requesting information about the teaching machines that they manufactured resulted in a poor return rate, even with the inclusion of a self-stamped addressed envelope. Second, it is likely that a standardized instrument facilitates more consistent responses to particular questions. The instrument did reduce the number of no returns, in cases where the correspondence actually reached the intended addressee.

While this review mentions several works concerned with the subject of the development of instructional devices and their related learning theories, it is not intended to be a review of all known works on the subject. This review of literature is intended to indicate the status of literature related to this subject and to describe and examine critically examples of such work. It is anticipated that the review of literature and the definitions presented earlier in the chapter will provide the reader with a basis and context that will clarify and facilitate the assimilation of information presented in subsequent chapters.

Chapter II

Instructional devices in the Ancient World

When the term *teaching machine* is mentioned, most individuals conjure up an image of rows of students seated in front of box-like objects, or students seated in front of some variety of computer terminal. Both images are accurate, but one of ancient Greeks and Romans using mechanical devices both for teaching aids and teaching machines is not one commonly envisaged. A prevalent misconception is that the technology of and the ideas behind teaching machines are a product of the twentieth century. As mentioned in the previous chapter, many contemporary works concerned with teaching machines credit two American psychologists, Sidney Pressey and B. F. Skinner, with their invention (Lumsdaine & Glaser, 1960; Kay, Dodd & Sime, 1968).

Other works, however, state that devices such as globes and orreries (mechanical planetaria) were introduced to teaching during the seventeenth century (Anderson, 1962). The prospect of the ancient Greeks or Romans possessing both teaching aids and teaching machines is not considered generally.

Greek devices

Archimedes' planetaria

While devices may have been constructed earlier that could have been considered teaching machines, the evidence available indicates that Archimedes (287-212 B.C.) produced some of the first. Among the machines he constructed were at least two that comprised spherical representations of the earth and important celestial bodies and which also, when a mechanism was turned, showed their relative motion. A book by Archimedes entitled *On Sphere Construction* supposedly describes both the construction and the application of his devices. The work has not survived, and other accounts must suffice (White, 1984). The earliest extensive description of these is provided by Cicero (106-43 B.C.) who also discusses their purpose and provides plausible explanations of why they were constructed (*De re publica*, 1. 14. 21-22).

From Cicero's description, it seems that the two were similar in construction, although one was more elaborate than the other. Each consisted of a larger central sphere (representing the earth) and smaller spherical representations of the moon, the sun, the five known planets and possibly other celestial bodies. It is important to note that the concept of a geocentric cosmos was prevalent during that time. How these smaller spheres were supported in relation to the central sphere is not revealed. Upon the movement of a mechanism by the user, the smaller spheres would revolve about the larger, following a path resembling their observed movements through the sky. The movement of these spheres was also relative, so relative position as well as phenomena such as eclipses were shown accurately. Cicero's description is cut short abruptly, since several pages of the manuscript are missing. Given this information, it appears that Archimedes' devices were mechanical representations of the cosmos as it was then understood. In many ways, the aforementioned devices appear to be similar in principle to modern orreries (mechanical planetaria). It may be asked from where the idea for showing the cosmos in this manner come? Cicero provides an answer.

Thales' globe

Cicero relays information from his friend Gaius Sulpicius Gallus, who describes a globe allegedly constructed by Thales of Miletus (ca. 550 B.C.) which Gallus believed to be a precursor to Archimedes' mechanical representation. According to Gallus, Thales' globe was solid, had several constellations painted on its exterior and was the first of its kind. It is further stated that the information on the globe was engraved onto it some years later, by Eudoxus of Cnidus. One may infer that the globe had probably been used extensively, so that the paint had worn thin; but its use was still important enough to justify the effort of engraving (*De re publica*, 1. 14. 21-22). This raises another question, for what was it used?

It seems that Thales' celestial globe was intended to show the constellations in much the same way that a modern globe shows the major continents of the earth. Thales' globe, therefore, was probably used for instruction in astronomy. If this is so, the globe may be classified as a teaching aid, since it was used to illustrate the location of stars in the sky. The globe had no means of accepting an input, performing a transformation and then presenting instructional feedback, and so it could not be considered a teaching machine. This observation does not mean that the usefulness of the globe was limited to its being used in conjunction with other forms of instruction. Cicero describes how the poet Aratus, who had no knowledge of astronomy, accurately described the heavens by simply studying the globe. From this account, it is apparent that Thales' globe could impart useful information without coincidental instruction from a lecturer, even though the globe could not simulate the motions of the celestial bodies. Cicero also mentions that the major disadvantage of Thales' globe was that it could not show the motions of the sun, planets or any other celestial body (*De re publica*, 1. 14. 21-22). Although the globe attempted to simulate the cosmos, the simulation was not complete, since the movement of the planets and the sun could not be reproduced. Why was the study and teaching of the cosmos of such importance?

Learning theory behind Archimedes' planetaria

According to Cicero the study of astronomy, as well as the understanding of the movement of celestial bodies, was necessary for one to obtain the knowledge of the gods. In Stoic philosophy, to possess the knowledge of the gods was both desirable and encouraged. Cicero states,

> And contemplating the heavenly bodies the mind arrives at a knowledge of the gods, from which arises piety, with its comrades justice and the rest of the virtues, the source of a life of happiness that vies with and resembles the divine existence and leaves us inferior to the celestial beings in nothing else save immortality, which is immaterial for happiness. (*De Natura Deorum*, 2. 61. 153-154)

It is a logical progression from this premise, that if one could obtain a better understanding of the heavenly bodies, one's knowledge of the gods would be more extensive.

If one can learn some information by studying a passive object such as a globe independently, *a fortiori*, an individual could learn even more by being able to interact with a device that produces recognizable interactive feedback dependent upon the user's input. By manipulating and observing a functional simulation of the cosmos, therefore, the operator could learn how his/her actions cause the *celestial bodies* to revolve around the *earth*, each in a peculiar but related manner. In addition, such a simulator can teach the user what occurs during a lunar eclipse. The idea of showing concepts in a concrete or a tangible way was an important consideration in learning at the time. Cicero notes that it is most difficult for individuals to be expected to believe that which they cannot observe (*De Natura Deorum*, 2. 37. 93-94). Archimedes' devices were able to demonstrate the idea that the abstract concept of the cosmos of that time was true. Besides transforming an abstract concept into a concrete simulation, Archimedes' planetaria could also show a *gods'-eye* view of the layout of the cosmos, as well as showing how the gods could control the movement of the cosmos. Cicero supports these views in his *Tusculan Disputations*. He states, "If that [the movement of the moon and the planets] cannot happen in the Universe without the action of a god, neither could Archimedes have copied those motions on a sphere without divine intelligence" (1. 63-64).

In the ways just described, Archimedes' devices could have been used as teaching machines. The fact that the concept of a geocentric planetary system was later proven to be erroneous does not diminish the validity of the pedagogical principles underlying Archimedes' planetaria. It is unlikely that they were primarily intended for any use other than teaching. It would not have been possible for them to be used as navigational aids, since there was no way of aligning the motion of the devices to any celestial bodies. It is also unlikely that the planetaria were used for predicting eclipses and other astronomical phenomena, since the user, not some form of time piece, had to cause the mechanism to turn. The planetaria were also not considered to be toys or gadgets. It should be noted that Archimedes fabricated the devices sometime before his death in 212 B.C. Cicero wrote his account of the planetaria at approximately 70 B.C., more than 130 years after they had been produced. He describes how they were removed from Syracuse, after its capture by Rome, by Marcellus, and that the more elaborate of the two was placed in the temple of Virtue where it was observed by many people and became widely known. The other planetarium, the one Cicero describes, was kept privately and was well taken care of (*De re publica*, 1. 14. 21-22).

Schlebecker (1977) describes four essential elements which are required before a technological invention can occur: (1) accumulated knowledge; (2) evident need; (3) economic possibility; (4) cultural and social acceptability (p. 650). In the case of Archimedes' planetaria, the first element is satisfied, since there was, evidently, more mechanical information available than had been available during the time of Thales of Miletus. Cicero's accounts illustrate that there was an evident need for mechanical representations of the movements of celestial bodies, in order for one to share in divine intelligence. The fact that at least two such devices were produced not only satisfies the second element, but it also satisfies the third and fourth elements. It is apparent that someone paid for the construction of the planetaria and since two were built, with one being quite elaborate, it follows that the cost of construction was not seen to be unrealistically high. Other pedagogues also constructed devices similar to Archimedes' planetaria. Such action indicates further support for the fourth element.

Posidonius' planetarium

Posidonius of Rhodes (a Stoic philosopher who had taught Cicero at one time) did make a similar although simpler replica of one of Archimedes' planetaria (*De natura deorum*, 2. 34-35). From Cicero's description, it seems that Posidonius' planetarium operated in the same manner as Archimedes' devices. It is likely, therefore, that the planetarium constructed by Posidonius was used as a teaching machine and possibly as a teaching aid as well.

Antikythera mechanism

A problem with three-dimensional simulations of the cosmos is that as they become more complex in design, showing more information, they also increase in weight and bulk (King & Millburn, 1978). To be sure, simple globes, orreries and other such devices similar in principle to Archimedes' planetaria have been used and continue to be used for educative purposes. To overcome the weight and bulk factors, however, it seems a logical progression to represent complex simulations in a planar fashion.

Evidence that the ancient Greeks encountered and dealt with this problem comes from the preserved fragments of the so-called Antikythera mechanism, which dates from approximately 80 B.C. The remains were discovered, during 1900-1901, in an ancient shipwreck located off the coast of the island of Antikythera, which is situated to the northwest of Crete (Price, 1974). The remains, which are badly encrusted and thus obscured, reveal that the device consisted of an array of bronze gears which, when a single drive shaft was rotated, moved several circular engraved bronze plates (Price, 1974).

Through extensive cleaning, and by means of radiographic analysis, it appears that two of the engraved bronze plates represented the sun and the moon. Small, evenly spaced marks on the plates suggest that they were intended to show movement by degrees. It also appears that the movement of the plates was in relation to an engraved zodiacal circle. A partially legible inscription on the rear rectangular plate seems to be a description of what is represented on the machine. It is also possible that the inscription contains instructions on how to set the apparatus (Price, 1974). References to pointers, in the inscription, as well as the aforementioned gradations on the rotatable plates, suggest that the machine was intended to show movement accurately. A question that arises at this point is what was the device used for?

Price (1974) states that the device appears to have been some sort of a hand-held "calendrical Sun and Moon computing mechanism..." (p. 13). As to its applications, Price is not certain, since the device is not complete. He also states that the device was not a navigational tool (p. 22). If the Antikythera mechanism was a portable hand-operated device, then it is possible that it was used as a teaching aid or even as a teaching machine. Price also refers to a critic of his research who contends that the Antikythera device is not ancient, but a modern orrery or a planetarium similar in design to one from which he had learned the fundamentals of the solar system in school (p. 12). Although scientific analysis has shown that the device is ancient, the readily apparent similarity between it and a modern planar orrery supports the contention that the Antikythera mechanism may well have been used for instructional purposes. It is also significant to note that the inscription on the rear rectangular plate implies that individuals could use the device on their own. If use of the mechanism required a trained operator, or an individual with extensive knowledge of calendrical calculation, then the inscription would have been superfluous. If it was possible for an individual to operate the mechanism without constant supervision, then it would satisfy the requirements of being a teaching machine. In addition, the device appears to have been used extensively, since there is evidence of a break and subsequent repair in one gear (Price, 1974). The evidence of repair also indicates that the Antikythera mechanism was not considered to be a mere gadget or an object for amusement. A paucity of contemporary evidence and information, however, prevents one from establishing exactly how the device was used and for what purpose.

Teaching aids also appear to have been used in the ancient world. Examples can be found in some of the devices invented by Hero of Alexandria (probably first or second century A.D.).

Hero's teaching aids

Kettle and sphere device

Cicero states, following a tenet of Stoicism, that he could not be expected to believe something, specifically a philosophical idea, unless he could observe some model or manifestation of it (Brumbaugh, 1966, p. 105). This tenet provides a possible explanation of the purpose of many of Hero's devices. Some appear to be teaching aids specifically intended to embody some demonstration of a philosophical idea. One such aid was the apparatus that was intended to support a small hollow sphere by means of a jet of steam. According to Hero's description, the device consisted of a kettle which was to be filled with water and then placed above a fire. The lid of the kettle was tight fitting and also had a small diameter tube projecting from the middle. A bottomless cup was attached to the top of the tube and the hollow sphere was placed in it (Hero, *Pneumatica*, 2. [illegible]). When the water boiled, the steam escaping from the tube would lift the sphere above the cup and would hold it stationary. Figure 4 (after Hero, *Pneumatica,* 2. 6) illustrates this arrangement.

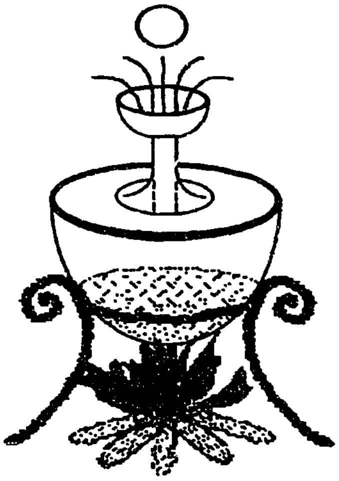


Figure 4. Teaching aid for demonstrating the power of pneuma

Although we know that aerodynamic forces hold the sphere in position, it is likely that Hero and other contemporaries believed that the suspended sphere represented a simulation of the Stoic concept of the earth being held in place in the cosmos by the Gods' *pneuma.* Stoics believed pneuma to be a rarefied material which not only supported the earth, but which was also responsible for the position and the order of the celestial bodies. This philosophy was in sharp contrast to that of the Epicureans, who held that rarefied materials could not support a denser object (Brumbaugh, 1966). It is possible, therefore, that Hero's device was a teaching aid that was used to illustrate how the earth was supported in the cosmos. This device could not be considered a teaching machine, since there is no user input, save that of lighting the fire under the kettle.

Glass hemispheres device

Hero produced another device, which illustrated further the Stoic concept of the earth supported in the cosmos. The previous apparatus required the use of steam, which is a rarefied material, but in rapid motion. A further proof of Stoic tenets consists of showing a representation of the earth supported by air that is stationary. In order to accomplish this, Hero devised an apparatus which consisted of two glass hemispheres and a bronze plate. The bronze plate, which rested on the lower hemisphere, had a hole cut in its centre. The hole's diameter was slightly larger than that of a small hollow sphere which was intended to be placed through the hole. The lower hemisphere was filled with water, and this supported the hollow sphere level with the bronze plate. The upper hemisphere was then placed on top of the bronze plate. Through some means, probably a small spigot in the lower hemisphere, some water was extracted from the assembly. It was intended for the hollow sphere to remain in position without resting on the surface of the water, thus proving that stationary air could support an object of greater density. Figure 5 (after Hero, *Pneumatica,* 2. 7) illustrates the likely appearance of this device.

At first glance it seems unlikely that this apparatus could perform such a function, but a modern model of it was constructed by the E. H. Sargent Scientific Company of Chicago, under the direction of Sherrick and Brumbaugh (Brumbaugh, 1966). The model functioned just as Hero had predicted. By means of this more elaborate model, it was

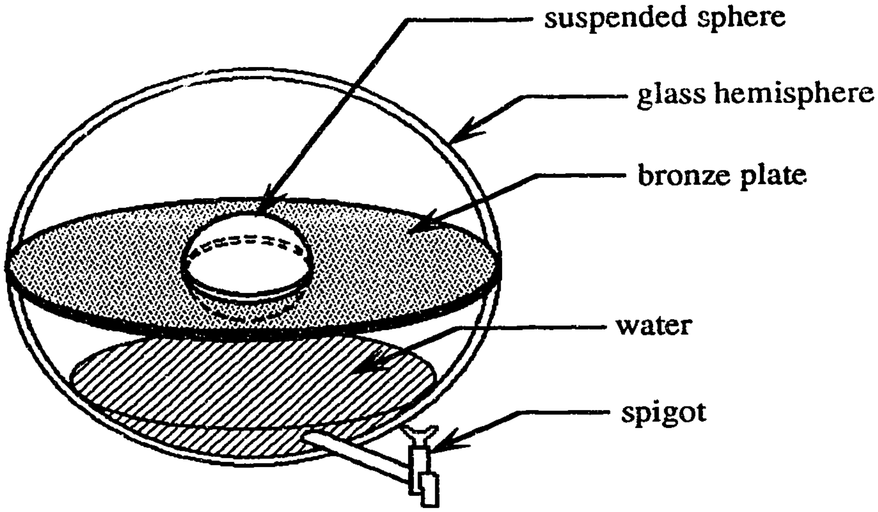


Figure 5. Apparatus for demonstrating the theory that stationary air can support a sphere

possible to make a case that stationary air could support a heavier object, although we know now that this was not actually what was happening within the apparatus. Brumbaugh (1966) points out that Hero's glass spherical model clearly refuted the Epicurean criticisms of this aspect of Stoic philosophy (p. 107). If Hero's glass sphere was used for this purpose, then there can be little doubt that it was used as a teaching aid for philosophy.

The devices discussed to this point were intended to illustrate some complex philosophy or philosophic principle, and were themselves mechanically elaborate. It is likely, therefore, that if they were used for instructional purposes, the individuals using them were adults. If, for example, one were to use Archimedes' mechanical planetaria, one would first have to know something about the concept of the cosmos at that time, or, at the very least, comprehend what the component parts of the apparatus were supposed to represent. If the user did not possess this information, then it is doubtful whether the user would learn anything useful from the apparatus related to cosmic theory. The same can be said about Thales' globe. The Antikythera mechanism, as well, required the user to have some knowledge of geometry and mathematics, since the rotatable plates appear to be marked with degree gradations. It may be asked whether there were any teaching aids and teaching machines intended for use with children and with individuals who did not possess a prior knowledge of a philosophy or a set of philosophical concepts? The answer is yes.

Roman teaching aids

Quintilian's pedagogical theory

Although most ancient elementary education appears to have consisted mainly of imitation, memorization and rote exercises, there is evidence which indicates that various teaching aids were used in some quarters (Graves, 1918; Marrou, 1956). Marcus Fabius Quintilianus, known as Quintilian, was a Roman teacher and rhetorician of the first century A.D. Some of his writings about his theories and practices of education have survived. Quintilian agreed with the idea that imitation was a very suitable means of education, but he also saw certain drawbacks in using it alone. He states,

> And it is a universal rule of life that we should wish to copy what we approve in others. It is for this reason that boys copy the shapes of letters that they may learn to write...The first point, then, that we must realise is that imitation alone is not sufficient, if only for the reason that a sluggish nature is only too ready to rest content with the invention of others. For what would have happened in the days when models were not, if men had decided to do and think of nothing that they did not know already? The answer is obvious: nothing would ever have been discovered. (Quintilian, *Institutio oratoria* 10. 2. 2-5)

Quintilian's condemnation of the predominant use of imitation extended to the beginnings of elementary education,

> At any rate I am not satisfied with the course (which I note is usually adopted) of teaching small children the names and order of the letters [of the alphabet] before their shapes. Such a practice makes them slow to recognise the letters, since they do not pay attention to their actual shape, preferring to be guided by what they have learned by rote. (Quintilian, *Institutio oratoria* 1. 1. 24-25)

Ivory letters

Quintilian advocated the use of objects which enable the student to formulate concepts of what was being learned. He states,

> I quite approve on the other hand of a practice which has been devised to stimulate children to learn by giving them ivory letters to play with, as I do of anything else that may be discovered to delight the very young, the sight, handling and naming of which is a pleasure. (Quintilian, *Institutio oratoria* 1. 1. 26)

Writing practice board

Quintilian also encouraged the use of teaching aids that would tend to develop a child's physical control of a sequence of desired movements. It was common practice, during Quintilian's time, for students to write upon hard wax tablets using a blunt stylus. The stylus was usually formed from wood or metal and was held in one hand. By drawing the stylus across the wax, in a manner similar to the way in which we use a pen on paper, a line, letter or shape could be engraved on the surface. It was not normal for students to write upon papyrus or parchment, because of their high cost. As well, the wax tablets were usually designed to be scraped down several times, thus presenting both a fresh writing surface and prolonging the use of the tablet, a feature not duplicated easily with a sheet of paper. Quintilian also notes that the use of parchment and a pen required repeated interruption of writing because the pen, usually a quill, had to be replenished with ink at frequent intervals. Such interruptions were considered by Quintilian to be detrimental to learning (Quintilian, *Institutio oratoria* 10. 3. 31-33). A great deal of skill was required to form letters legibly on the tablet, given the hard surface of the wax. It would appear, from Quintilian's account, that many students had initial difficulty in writing. Apart from the difficulty in writing on wax, the beginning student would not be familiar with the proper sequence of moving his/her hand, wrist and arm to form each letter correctly. The student, in such a case, would be attempting to master two skills at once; forming the letters correctly, and writing on wax. Quintilian recognized this problem and devised a solution. He recommended that the teacher prepare a wooden practice board for each pupil. The board was to have each letter of the alphabet engraved on it. The pupil would then practice tracing each letter, using the stylus. The stylus would tend to follow the grooves in the wood, thus guiding the student's hand, wrist and arm throughout the tracing of each letter. With additional practice, the student would become familiar with the motions necessary to form letters correctly, and would thereby develop appropriate muscular control. Quintilian states,

> Thus mistakes such as occur with wax tablets will be rendered impossible; for the stylus will be confined between the edges of the letters and will be prevented from going astray. Further by increasing the frequency and speed with which they follow these fixed outlines we shall give steadiness to the fingers, and there will be no need to guide the child's hand with our own. (Quintilian, *Institutio oratoria* 1. 1. 27-28)

Although Quintilian's claim of eliminating mistakes on the wax tablets is likely an exaggeration, it is apparent that his method would provide some practice in the forming of letters, so that when a student attempted to write on the tablet, the primary difficulty experienced would be getting used to manipulating the stylus on the wax. Apart from providing the student with a means of individualized practice, this method also enabled one teacher to instruct several pupils simultaneously, without an undue concern that those not receiving assistance were not writing properly.

One may ask why Quintilian's practice board is considered to be a teaching aid rather than a teaching machine, since there is input by the user and there is instructional feedback. According to the definitions set forth at the outset, the practice board is not mechanical. The board is not capable of performing some form of transformation. The transformation is performed solely by the user. The board is not, therefore, a teaching machine. In addition, the practice board was intended to be used in conjunction with a teacher, as an adjunct to instruction in writing.

Quintilian's performance objectives

The above two teaching aids devised by Quintilian may appear, initially, to be concerned with a single learning outcome or performance objective, to write the alphabet, a psycho-motor activity. Although Quintilian did not say so in scientific terms, his teaching aids deliberately addressed different learning outcomes. Modern psychologists and educational theorists such as Bloom and associates (1956) and Gagné (1984) have also divided *learning outcomes*, or *performance objectives* into categories or domains. Although such taxonomies were unknown to Quintilian, his deployment of teaching aids for different pedagogical purposes, reflects an empirical knowledge of distinct and separate performance objectives, each of which requires a different pedagogical approach.

The use of ivory letters as an aid for children to form concepts of the letters of the alphabet indicates a concern for cognitive development, while use of the practice board indicates a performance objective concerned with motor or psycho-motor development. Quintilian also advocated teaching aids for activities which we could now consider to be concerned with attitudinal or affective development. He states, "There are moreover certain games which have an educational value for boys, as for instance when they compete in posing each other with all kinds of questions which they ask turn and turn about. Games too reveal character in the most natural way..." (Quintilian, *Institutio oratoria* 1. 3. 11-13).

Although Quintilian did not actively divide performance objectives into the domains or categories described by modern theorists, it is apparent that a similar empirical division had been utilized. This observation supports the belief that Quintilian's use of teaching aids arose from the analyses of pedagogical problems: there was an evident need for them. Recalling Schlebecker's four elements for technological invention one may argue that Quintilian had enough accumulated knowledge to create the teaching aids, that there was an evident need, and that they were, for the most part, economically feasible. An evident weakness within the fourth element, cultural and social acceptability, provides an explanation why such teaching aids were not widely used throughout the ancient world. A major thrust of Quintilian's work was the criticism of other pedagogical approaches (Quintilian, *Institutio oratoria* 1. pr. 23-26; 1. 3. 13-18). While he may have believed his methods and his use of teaching aids to be the best, it is more than likely that others did not.

Other Roman devices

Finger reckoning

We have seen how teaching aids were employed by Quintilian to assist in the instruction of basic writing and letter recognition. There is some evidence available that indicates that devices of a similar nature were used in the instruction of mathematics and arithmetic. Techniques such as finger reckoning, which entails ascribing numeric values to each finger and combinations of fingers according to an accepted pattern, were known to have been used extensively in the ancient world (Menninger, 1979, Vol. II). Quintilian mentions finger reckoning as an analogy to oratory, "If a speaker, by any uncertain or awkward movement of the fingers differs from the accepted mode of calculation, he is thought poorly trained" (Quintilian, *Institutio oratoria* 1. 10. 35). While Quintilian's statement indicates clearly that finger reckoning was used as an aid for calculation, it is not clear whether such a method was used for instruction in arithmetic, such as in addition and subtraction. It seems reasonable that a teacher could hold up three fingers on one hand and then two fingers on the other in order to illustrate tangibly how the sum of five was obtained by addition. This technique could enable the student to form a concept of the principle of addition. This idea would be congruent with Quintilian's philosophy of pedagogy. In such a case, the fingers would be used as teaching aids. There is no evidence, however, that supports this idea unequivocally.

Gaming pieces

A few ivory gaming pieces have survived which may have been used as teaching aids. The pieces, dating from the first century A.D., are circular with a diameter of approximately 29 mm, and a thickness varying between 2 and 4 mm. One side is engraved with a depiction of a hand holding up one or more fingers, while the other side is engraved with the corresponding Roman numeral. Figure 6 (after Menninger, 1979, Vol. II, p. 14) is an example of one of the gaming pieces.

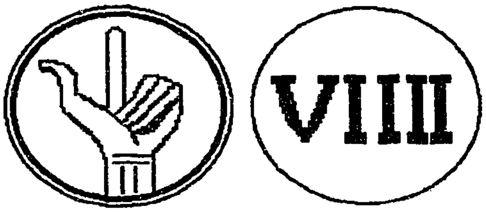


Figure 6. Obverse and reverse views of a Roman gaming piece

While it is likely that this type of gaming piece was used as a counter in a board game, it is also possible that they were used for quizzing purposes, in much the same manner that *flashcards* are used today. In either application, the gaming pieces would have served either to provide new information, or to have reinforced previously learned information. The gaming pieces would be considered teaching aids, therefore.

Abacus

The abacus was also ubiquitous in the ancient world (Williams, 1985; Menninger, 1979, Vol. II). As with finger reckoning, there is some evidence that suggests that the abacus may have been used for instructional purposes (Pullan, 1968). The Roman poet Horace (65-8 B.C.) describes boys travelling to school carrying their abaci, "hanging from their left arms the counters and the tablet" (*Satires*, 1. 6. 73-74). The earliest known ancient abaci consisted of some planar surface, usually a stone table top, onto which were inscribed lines. A line could represent units, or it could represent some form of multiple increment or fractions of unity. The significance of each line was sometimes indicated on the abacus as well. Small objects called counters (initially pebbles were used) were placed along the lines to represent numbers (Menninger, 1979, Vol. II). Surviving examples of ancient Greek abaci and depictions and writings of that period indicate that the table type of abacus was used primarily as an aid for calculation (Richardson, 1916; Williams, 1985). It is possible that these large early abaci were also used as teaching aids. By placing and manipulating counters on the abacus table, a teacher could show an individual student, or several students simultaneously, the concepts of addition and subtraction. Once the concepts had been learned, a student could then perform similar calculations on the abacus without help.

The Romans developed a hand-held version of this type of abacus. Surviving examples consist of bronze tablets, about the size of a postcard. The *lines* consist of slots into which are placed small grooved counters. Each slot is labeled as to its value (Menninger, 1979, Vol. II). This apparatus would be used in a similar manner to the larger version (Kretzschmer, 1978). Figure 7 (after examples in the British Museum, London; Museo Nazionale, Rome) depicts a hand-held Roman abacus of the type just described. The abacus is displaying the number 1,005,372.

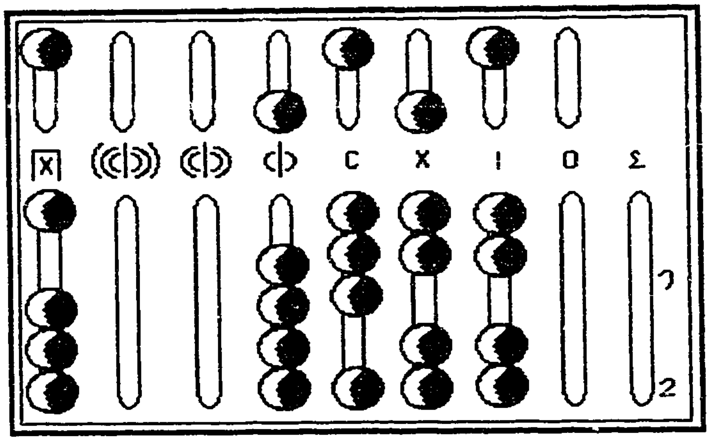


Figure 7. Hand-held bronze Roman abacus

Neither type of abacus was mechanical; the counters were separate, manipulated by the user. This style of abacus, therefore, can be considered to be a teaching aid, in addition to its primary function as a calculator. It is important to note that the bead type of abacus, with which we are familiar, seems to have been developed during the mediæval period in the Middle East. From there its use spread as well to the orient (Williams, 1985).

Teaching machines for physical training

So far, we have examined teaching machines and teaching aids that were used in conjunction both with the instruction of philosophy and with the instruction of academic subjects such as writing and mathematics. A significant area of instruction that has not yet been dealt with is physical training. In addition to the philosophical tenet of ***Mens sana in corpore sano*** [a healthy mind in a healthy body] (Juvenal, *Satires*, 10. 356), the ancient Greeks and Romans placed strong emphasis on such physical training as would result in the production of strong and superior soldiers. Physical training was also considered very important for such individuals as professional pugilists and gladiators, who comprised a significant segment of ancient entertainment.

Korykos

The training of pugilists in ancient Greece included extensive practice in correct punching techniques. A successful pugilist was also required, simultaneously, to dodge punches from his opponent. While sparring matches could provide such practice, they entailed the use of two individuals and an appropriate location. Individual practice was realized by means of a special punching bag called a *korykos* (Aristotle, *Rhetorica*, 3. 11. 13). It was suspended from a ceiling or an arbor in such a way that upon being punched it would swing away from the pugilist in an arc. The korykos would then swing back towards the pugilist who was expected to avoid contact with it. Depending upon how it was suspended and the force of the pugilists' blows, the movement of the korykos could be quite rapid. Although it was not as elaborate a sparring partner as another pugilist, it functioned as an adequate teaching machine for both punching technique and dodging. The *input* to the korykos were the initial punches of the pugilist. The *transformation* was the motion of the korykos in an arc about the pugilist, and the *instructive feedback* was either the korykos hitting the pugilist, or the pugilist avoiding it. Avoidance of the blow indicated to the pugilist that what he was doing was appropriate.

Palus

Roman entertainment included displays by gladiators. Despite the portrayal provided in many contemporary screen plays, that gladiators were disgruntled slaves or wild barbarians, most of them were highly trained individuals who were expected to perform, in a skilled manner, a variety of hand-to-hand conflicts with different weapons. It was expected that most gladiators would survive at least a few engagements, since patrons usually paid, and paid considerable sums, for the training of individual gladiators. Most gladiators were taught in *ludi*, training schools that were owned usually by prominent individuals.

Training included complete control of the gladiators' environment and actions, with rewards given for appropriate behavior, and punishment administered for undesirable behavior (Quintilian, *Declamations*, 9.). The system resembled some behavioristic approaches to pedagogy (Watson, 1930). Teaching aids were used in the training of certain gladiatorial skills, such as the correct handling of a sword. The proper use of a sword was necessary for two reasons. First, proper sword manipulation would result in a hit or an injury of the opponent. Second, proper sword techniques would limit the likelihood that the attacker would leave himself open to a retaliatory thrust or slash. Intense practice was seen as the primary method by which a gladiator would become proficient in the proper handling of his sword. Instead of having gladiators practicing against one another, where injury could occur, a *palus* or post was used by each individual. A palus was some form of wooden shaft or post stuck into the ground, so that it projected vertically about six feet (1 800 mm) (Vegetius, 1. 11). Using a practice sword and shield, the rookie gladiator was expected to attack that palus as if it were an opponent (Vegetius, 1.

11). The purpose of the exercise was to reinforce the instruction received on proper sword techniques. Although it is not stated in the sources, it is reasonable to assume that instructors supervised such training sessions and intervened if they observed improper technique. Initially, it seems that spears were used as *pali,* since an illustration on a lamp tondo depicts a gladiator training against a spear. Figure 8, (after Daremberg-Saglio, p. 1582), shows a gladiator training against a spear palus.

Figure 8. A gladiator training at a palus

The use of a spear palus probably gave way to a more substantial post, since it was desired that the pali be rigid during training (Vegetius, 1. 11).

The rigors and the merits of gladiatorial training were recognized as belonging to a superior technique as early as 105 B.C., when the Consul Publius Rutilius introduced these methods into military training (Valerius Maximus, 2. 3. 2). While there were some within the army who did not approve of such radical changes, the success of Rutilius' legions convinced others. Frontinus (*Strategmata,* 4. 2. 2) notes, "Gaius Marius had the opportunity to select his army out of two already in existence, the army which had served under Rutilius and the one which had been under Metellus...He chose the army of Rutilius even though it was smaller, because he thought it to be better trained" (Vegetius, 1. 11). The palus was also an aspect of gladiatorial training that figured prominently.

One problem with the palus was that it could not indicate to the user whether the techniques used were appropriate or not. It is possible, therefore, that poor habits of an individual could be reinforced for considerable time before a supervisor appeared to correct them. To overcome this problem, a device was required that would provide immediate feedback to an input; a teaching machine. Although accounts are vague from Roman times, it seems that such a device was invented during that period. It was called the *quintain* (Kuret, 1963).

Quintain

Training at the palus usually occurred along the fifth street of a Roman military camp (Connolly, 1981). The fifth street, called *Quintana,* gave its name to an improvement of the palus which transformed it from a teaching aid into a teaching machine. There is at least one modern author (Clare, 1983) who claims that the quintain may have received its name in honour of a man named Quintus who was its supposed inventor, but this seems to be no more than false etymology (Kuret, 1963).

There are several known varieties of quintain, but all operate according to one principle. A vertical shaft, usually of wood, supports a horizontal arm on top of the shaft. The arm is arranged so that it will pivot freely. One end of the horizontal arm holds some form of target. The other end supports a counterweight which could be in the form of a weapon or other pain-inflicting instrument (Kuret, 1963). The operation of the quintain was simple. Input was provided by the user who either aimed or struck at the target. Depending upon the intended purpose of the quintain, the target would either remain stationary or would swing away from the user. This transformation of the input would result in some form of feedback. If the intent was for the quintain to remain stationary, movement of the target would be an indication that the input was not correct. Conversely, if it was intended that the target be moved by the input, a stationary quintain would be an undeniable indication that the input was incorrect. If the blow was correct and the target swung away, the user would also have to dodge the counterweight or weapon. The concept of a device that would accept an input, perform a transformation and then provide some form of instructive feedback was not new to the Romans. It should be recalled that some Greek pugilists were trained by means of a korykos. It is logical to assume, therefore, that the Romans were able to meld the concept of the korykos with that of the palus in order to produce the quintain. Evidence to support this premise can be found in the writings of Flavius Vegetius Renatus, called Vegetius (fourth or fifth century A. D.). In his description of the training of recruits, he states

> they used to learn to strike not with slashing but with thrusts. For the Romans not only easily beat those slashing but also laughed at them. For a slash, wherever one might make an attack, does not usually kill, since the vital areas are protected by weapons, armour and bones. On the other hand, a thrust made two inches deep is mortal; for whatever is thrust in inevitably goes into vital areas. (Vegetius, 1. 11. 12; translation, Buck)

Training solely on the palus would not be satisfactory for a recruit who was expected to learn to thrust rather than to slash. Without immediate feedback, it would be possible for a recruit to develop a habit of slashing before being corrected by a centurion or some other trainer. In addition, a solid wood palus is an inappropriate aid in training recruits to thrust two inches (50 8 mm). It seems much more likely that Vegetius is describing recruits training with quintains. This sentiment is also supported by Kuret (1963). Given both Vegetius' description of military training and the criticisms of the suitability of the palus, the author has prepared a drawing of a quintain that was likely used for training army recruits to thrust rather than to slash with their swords. The design is based upon the descriptions and the depictions of pali as well as mediaeval quintains. Figure 9 depicts the author's concept of a Roman quintain. The target, the large object on the right-hand side, was likely a burlap or a leather pouch filled with soft, light material, possibly straw. It is not known what the counterweight contained, but it is likely to have had a sufficient mass to balance the target. It is also likely that the mass of the counterweight was not too great, so that the quintain would rotate if it were struck with too great a force.

Conclusions and implications

This chapter has described several teaching machines and teaching aids produced and used in the ancient world. They indicate that the concepts of individualized instruction and of employing technology in pedagogy are not new. It is important to note that there were two major areas where teaching machines were used: first, instruction in Stoic tenets (philosophical instruction); and, second, military training. While some facets of military training continue to employ devices similar in principle to the quintain, philosophy has shifted away from using instructional devices both to explain and to teach abstract concepts. The decline of Stoicism may have been a cause of this shift.

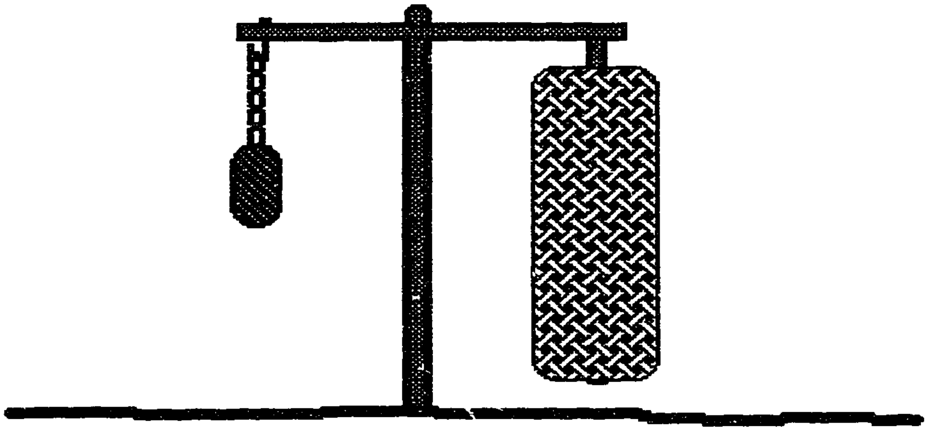


Figure 9. Probable appearance of a Roman quintain

It is also important to note that some teaching aids similar to those devised by Quintilian and some teaching machines similar to Archimedes' spheres continue to be used. One may infer that continued use of such teaching machines and teaching aids indicates the soundness of pedagogical principles that are as much in use today as they were more than two millennia ago.

The purpose of the chapter is not to advocate a return to earlier methods, but to provide information that may be applied in a useful manner to current and future developments in education, many of which parallel those of the ancient world. Above all, a knowledge of past successes and failures will assist in diminishing senseless *reinvention of the wheel.* It is possible, for example, for one to encounter modern advocates of computer-assisted instruction who ponder the merits of the same pedagogical ideas as those expounded by Cicero more than two millennia ago, "Instead of describing a solar system or some theory about it, you might construct a computer simulation and allow people to discover their own theories by interacting with the simulation" (Levine & Rheingold, 1987, p. 233). A knowledge of the success of Archimedes' planetaria in enabling self-discovery of tenets of Stoic philosophy might have resulted in such a program being available now, rather than just being considered. Although some benefit can be derived from knowledge of ancient teaching machines and teaching aids, such knowledge does not mean that all contemporary pedagogical developments and innovations are mere rehashing of ancient ideas and principles. The next chapter describes some of the developments that occurred during the mediæval period. It will be shown that not all of the instructional theories or instructional apparatus devised during that period were a linear development from ancient innovations.

Chapter III

Teaching machines and teaching aids in mediæval times

It is contended in the previous chapter that both teaching aids and teaching machines were used in the ancient world. The teaching machines from that period were used in two major areas: instruction in philosophy, as typified by Archimedes' planetaria; and military or gladiatorial training, as exemplified by the quintain. A myth held amongst some contemporary educators and educational theorists is that the present state of education is the result of a continuous development of educative and pedagogical ideas and principles from ancient foundations (Skinner, 1961; Fine, 1962). If this premise were valid, then it would follow that the teaching machines and the teaching aids devised by the Greeks and Romans would have been further developed and used for educative purposes throughout the mediæval period. Such was not the case: some instructional devices continued to be employed, but others died out or virtually disappeared from use as the result of several factors which will be identified and discussed. A few new instructional devices were developed as well. Although an unbroken development of such technology from ancient antecedents did not always occur, examples of both teaching machines and teaching aids can be found that appear to have been used almost unchanged during most of the mediæval period.

Definition of time period

For the purposes of this treatment, the mediæval period will be considered to extend from the collapse of the Western Roman Empire in the fifth century (traditionally 476 A.D.) through to the year 1500. To facilitate the discussion of mediæval teaching machines and teaching aids, it is helpful to consider the mediæval world as four distinct and largely separate divisions: (1) the West, including the British Isles, Ireland and most of the European territories that had been in the Western Roman Empire; (2) the Byzantine world, comprising the Eastern Roman Empire and a portion of Russia; (3) the Islamic world, including territory occupied or controlled by Muslims; and (4) the East, comprising China and India. Although there was some trade and social intercourse between the different divisions, intellectual communication and the exchange of ideas was at a minimum during the mediæval period. The developments of teaching machines and teaching aids in each area will be discussed.

Status of ancient devices

By the time of the collapse of the Western Roman Empire, Stoicism was no longer a major ideology; it had been replaced by Neo-Platonism and Christianity. The decline of Stoicism meant that teaching machines and teaching aids for the instruction of that philosophy through concrete means were no longer required. Christianity and Neo-Platonism, as well, actively discouraged such concrete analogies, preferring the individual to accept their tenets on faith and on arguments developed from a premise (Stevenson, 1921). Recalling Schlebecker's (1977) four criteria that have to be met before a technological invention can occur and then succeed: (1) accumulated knowledge; (2) evident need; (3) economic possibility; (4) cultural and social acceptability (p. 650), it becomes apparent that the disappearance of Stoicism also displaced both the need and the social acceptability of the teaching machines for philosophy. The demise of Stoicism did not affect the development of all known ancient teaching machines and teaching aids, however.

Quintain

It is stated in the previous chapter that it is likely that the quintain was developed during Roman times for the training of gladiators and soldiers (Vegetius 1. 11). The quintain had practical applications which addressed perceived needs of training which were independent of any philosophical ideology or religious belief. There is ample evidence to show that the quintain not only survived in the mediæval West, but that it was both improved and adapted to several varieties of military exercise (Kuret, 1963; Clare, 1983). One of the earliest known drawings of a mediæval quintain depicts a device which resembled closely the presumed appearance of ancient quintains. Instead of a large pouch as a target, however, this mediæval quintain employed a rectangular wooden board with a painted design as a target. This particular quintain, depicted in an English manuscript of the fourteenth century, was used for teaching proper techniques for the lance (Clare, 1983). The painted target, therefore, would have represented a shield. The principle of operation of this quintain was the same as that for the ancient quintains. Figure 10 (after an illustration in an English manuscript of the fourteenth century) depicts the appearance of a fourteenth century English quintain.

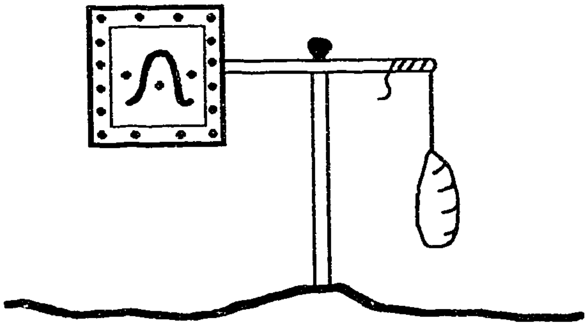


Figure 10. Quintain of the fourteenth century A.D.

The use of the quintain was not limited to the West. The Byzantine legal compilation, the *Codex Justinianus* of the sixth century, mentions the use of the quintain (Clare, 1983). The available evidence does not indicate any use of the quintain in the Islamic world or in the Orient. *Prima facie,* it seems likely that the knowledge of such a useful device probably did spread to these areas at some time during the mediæval period.

At some early point the appearance of the quintain in the West changed. Instead of being simply a featureless utilitarian device, it was sometimes redesigned to personify common criminals or the predominant enemy of the time, Saracens or Turks, for example (Kuret, 1963). This was achieved by incorporating a wooden figure into the main body of the quintain. In most examples, the vertical shaft that was stuck into the ground supported a carved wooden figure. The figure was so arranged that it could pivot around the shaft. One arm of the figure would hold a shield or some other target. The other arm was usually extended and its hand held some sort of weapon. The operation of this type of quintain was essentially the same as the simpler earlier variety. Figure 11 (after a French illuminated manuscript of the 1400s) depicts a knight practicing his lancing skills against a wooden quintain that was made in the likeness of an enemy.

Making a quintain resemble a human being did not improve its operation, but the personification may have added motivation and interest to the exercise and would thus have added to the appeal of this type of teaching machine. By practicing with the lance against an image of the enemy, for example, a trainee might obtain a measure of both intrinsic and extrinsic reinforcement that would not be readily apparent with a device that did not personify the enemy. Although no source states whether this was the intention of

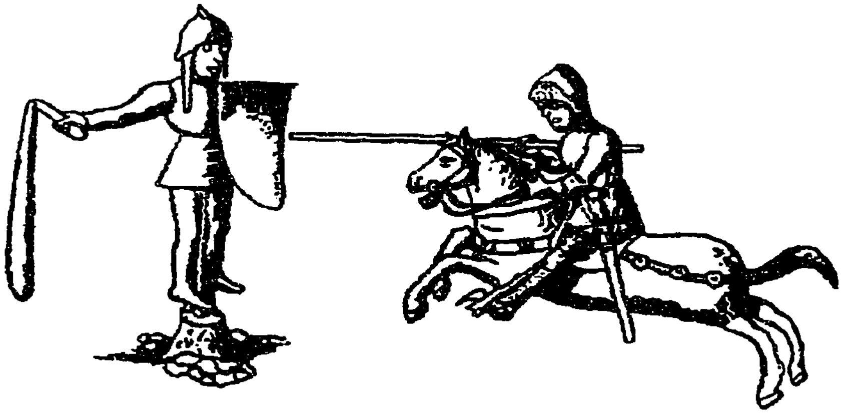


Figure 11. Knight practicing lancing against a quintain

incorporating wooden figures into quintains, it is reasonable to assume that this was so, since quintain exercises were considered suitable entertainment at jousting tournaments and at wedding parties (Kuret, 1963).

Although gladiators were not present in the mediæval world, military-style entertainment was still much in demand, at least by the Age of Chivalry. Instead of watching gladiators, the public was treated to displays by knights, as in jousting tournaments. As early as 1240 such tournaments were considered suitable entertainment for special occasions such as weddings (Clare, 1983). While the observers did not interact directly with the quintain and, therefore, learned nothing directly from it, the presence of a large group of people, who would cheer at success and jeer at failure, probably served to amplify to the knight the feedback provided by the quintain; this may well be termed extrinsic reinforcement. The knight might also experience some intrinsic reinforcement by considering a successful attack on a quintain as emotionally equivalent to destroying a part of the enemy. It is clear that in addition to being a teaching machine, the quintain also served as a form of entertainment. This is probably the first time a teaching machine may be observed to possess such a dual purpose.

The use of the quintain as a teaching machine and as an object for amusement continued throughout the mediæval period and beyond, despite political, social and philosophical changes (Kuret, 1963). It seems that since the quintain was purely a practical instrument that did not embody any articulated philosophy, which would be subject to both interpretation and social acceptance, the quintain survived as a teaching machine until the combat skills it taught became obsolete.

Learning theory of the quintain

It may be argued that the quintain incorporated aspects of what is now termed *operant conditioning* (Skinner, 1954). This behavioristic psychological theory is contentious when applied as a pedagogical method. Although some psychologists such as B. F. Skinner have identified particular pedagogical approaches as employing the principles of operant conditioning, there is no evidence to suggest that, during the mediæval period, the quintain embodied a *recognized* pedagogical or psychological principle. In this case, therefore, the observed effective results of the quintain as an instructional device were probably the most important factor in ascertaining whether it should be used or not. It would appear that practicality and the entertainment value of the quintain were also main reasons for its continued use. Although practicality was a major criterion in determining whether or not an instructional device intended for military training was efficient and appropriate, there are examples that indicate that practicality was not always an important factor in determining the development and the continued use of an instructional device.

Finger reckoning

Some ancient authors, notably Quintilian, have indicated that finger reckoning was in widespread use in the ancient world. Sometime after Quintilian's account, finger reckoning appears to have fallen largely into disuse in both the West and in the Byzantine world, since two authors of the eighth century A.D. found it necessary to write extensive works about finger reckoning advocating its use (Richardson, 1916). The earlier account was written by an English monk known as the Venerable Bede, while the other was written in the Byzantine world by Nicolaus of Smyrna. Bede, who wrote in Latin and possessed an extensive collection of ancient works, described in detail the position of each finger and hand for many numbers between 1 and 90,000 (Richardson, 1916). When one compares Bede's description of reckoning with examples shown on Roman ivory gaming pieces, it seems that Bede was reusing the Roman system of finger reckoning, and so it is likely that Bede was obtaining this system from ancient sources rather than devising a new system. It appears that neither the Venerable Bede or Nicolaus of Smyrna advocated the use of teaching aids for the instruction of finger reckoning. It is possible, however, that finger reckoning was used as a teaching aid for the principles of arithmetic at particular times during the mediæval period.

An illustration in the thirteenth century *Codex Alcobatiensis* (in Smith, 1958, p. 198) depicts several hand positions and the numbers they signify indicating that finger reckoning was still extant at that time. It is likely, therefore, that finger reckoning saw greater use than it had during the time of the Venerable Bede. Smith (1958) states that one condition that contributed to the prevalent use of finger reckoning during the mediæval period was the large number of illiterate individuals. An illiterate, who could neither recognize or write specialized symbols such as numerals, and thus had to use finger reckoning for any complex calculations, would likely have been taught the principles of arithmetic through concrete example such as the use of fingers. The fingers of the instructor would have been used initially as teaching aids, therefore. Once the learner had understood the principles of arithmetic, the fingers would be used as aids to calculation rather than teaching aids, since the primary purpose of finger reckoning was as a means of calculation rather than as a learning method. It is important to recognize, however, that the need for using concrete examples in certain pedagogical situations was still evident and accepted in the mediæval world.

Limitations to the use of teaching aids

It should be recalled that Quintilian advocated teaching aids that would enable a student to conceptualize what was being taught. The existence of ancient Roman gaming pieces also suggests that teaching aids were used in conjunction with instruction in finger reckoning (see Chapter II). The question that may be asked, given the comments of the Venerable Bede and Nicolaus of Smyrna about finger reckoning, is whether the general use of teaching aids was actively discouraged, or whether teaching aids were considered to be a hindrance rather than a help to instruction. While it is impossible to provide an irrefutable answer, as far as the Venerable Bede and Nicolaus of Smyrna are concerned, some evidence indicates that the use of teaching aids and teaching machines in the West was largely neglected during the first half of the mediæval period. This trend does not seem to have been a universal phenomenon, since there is evidence to indicate that the Islamic world had continued the Hellenistic tradition of using teaching aids and teaching machines, as well as developing new instructional devices (Winter, 1956).

Islamic devices

Demonstrational armillary spheres

Price and Wilson (1955) state that the writings, theories and instruments of ancient astronomers such as Ptolemy were known in the Islamic world as early as the ninth century A.D. Although it is generally accepted that Ptolemy devised armillary spheres solely for navigational and observational purposes (King & Millburn, 1978) there is evidence to indicate that such apparatus was modified in the Islamic world, so that it could be used for instructional purposes (Price, 1954).

An armillary sphere usually consists of a number of concentric and intersecting rings which represent the orbits of particular celestial bodies (mainly the known planets) and the path of the zodiac. The rings are arranged to form an outline of a sphere around a small, centrally located sphere that represents the earth. The assembly is usually mounted on a shaft and the rings can be arranged to either move around the central sphere, or they can be fixed in one position. The apparatus may also contain some means of aligning it to the pole star or some other designated celestial body. In such cases, the armillary sphere is usually intended for navigational purposes (Price, 1954; King & Millburn, 1978). Price (1954) notes the existence of several armillary spheres of Islamic origin that were not constructed with sighting apparatus and which were both smaller and simpler in design than those intended for navigation or calculation. He concludes that these simpler armillary spheres were used as demonstrational devices. He also postulates that these demonstrational armillary spheres are ultimately descended from the planetaria designed by Archimedes. Conclusive proof is not available, however. Price (1954) does not elaborate how demonstrational armillary spheres were employed, but it seems likely that they were used as teaching aids, possibly to show relative position of planets and other celestial bodies. It could be, as well, that demonstrational models were used as adjuncts to instruction in the use of navigational armillary spheres. A possible rationale would be that a simpler version is easier to understand. A simple model, as well, could be less expensive to construct than the actual device, if the intent is to show basic principles only. Materials, accuracy of construction, and the inclusion of details could all be compromised on a model sphere without adversely affecting the principles of use. While it is possible that such demonstrational armillary spheres were constructed for purposes other than instructional, it seems likely, given the established historical antecedents, that the Islamic world continued the ancient Greek and Roman tradition of employing teaching aids.

Learning theory

It has been noted at the outset of this chapter, that the apparent rationale of the ancient Greeks and Romans for using teaching machines and teaching aids was either to demonstrate philosophical tenets of Stoicism, or to provide tangible examples of a concept or a method. Teaching machines and teaching aids intended to prove a philosophy or religious beliefs through demonstration would not have been appropriate in the Islamic world, since Islam insists upon faith among its followers. It seems, therefore, that the underlying demonstrational aspects of the ancient teaching machines and teaching aids were retained while the original rationale for the development of the devices was either discarded or ignored. While there is no direct evidence, it may be inferred that the *evident need* for such devices was responsible for their continued use. The evident need would have been the realization of the pedagogical advantages of using teaching machines and demonstrative teaching aids over traditional lecture methods. Recalling Schlebecker's (1977) four criteria for technological invention and protracted use, it is apparent that these devices satisfied the criteria, since the devices not only existed but were used. It may be inferred further that the learning theories employed, either explicitly or implicitly, did not interfere with the tenets of Islam.

Astrolabic teaching aids

It is mentioned in Chapter II, that globes and planetaria were used for instructional purposes in ancient Rome. While such globes and planetaria provide a realistic simulation of the cosmos insofar as it was understood at that time, such devices tended to be bulky and difficult to store and handle. By the time of the mediæval period, Islamic navigation and astronomy largely relied upon compact instruments that could present most of the information found on older devices, and could also be able to perform complex calculations and measurements (King & Millburn, 1978). One such instrument was the planispheric astrolabe. This device consists of a large engraved or marked circular metal plate which encompasses several smaller engraved solid plates or engraved openwork wheels arranged to move within the confines of the larger plate. A pin placed through the centre of the larger plate supports a specially-designed pointer called an *alidade* which was designed to revolve freely about the pin. A boss and ring attached to the circumference of the larger plate enables the astrolabe to be suspended vertically for observational work (King & Millburn, 1978). In addition to showing the relative position of important celestial bodies, the planispheric astrolabe could also demonstrate relative motion of celestial bodies as well as their elevation above the horizon. While the main purposes of planispheric astrolabes were measurement and calculation, King and Millburn (1978) believe that they were also used as teaching aids. An understanding of the relative motion of the planets and particular stars was an important concept to understand if one were to succeed in astronomical endeavors, and most astrolabes could demonstrate this concept. In addition, through the use of the alidade, an instructor could demonstrate that given celestial bodies were at a measurable altitude above the horizon and that their altitude varied as time passed.

As with celestial globes and armillary spheres, there is little direct evidence to show that planispheric astrolabes were used as teaching aids in the Islamic world, although their use may be inferred, since it has been argued that their later use in the West originated from similar use in the Islamic world (Price, 1954; King & Millburn, 1978). Gingerich (1986) also contends that a knowledge of astronomy and, therefore, the requisite astronomical instruments, was considered important early in the Islamic world because of the religious necessity of an accurate lunar calendar.

There is additional evidence from which it may be inferred that planispheric astrolabes were used as teaching aids. Several examples exist of simple and crudely-constructed astrolabes called *pseudo-astrolabes*. While some examples appear to date from the nineteenth century, others are of an indeterminate date and may represent early examples of simpler astrolabes intended for use as teaching aids (Gibbs & Saliba, 1984). Gibbs and Saliba (1984) state that pseudo-astrolabes were likely constructed by individuals who did not understand how a true astrolabe actually functioned, yet they also indicate that some of the pseudo-astrolabes will perform the functions of a true astrolabe, but inaccurately. Although Gibbs and Saliba (1984) conclude that such crude but functional devices were the products of individuals ignorant of proper astrolabic construction, it may be argued that this view is erroneous if the so-called pseudo-astrolabes were intended to be teaching aids in the fashion of demonstrational globes and armillary spheres. If the intention is to provide instruction with the device only, then it would be superfluous and unnecessarily expensive to use an actual astrolabe. Precision astrolabes may be damaged if they are handled incorrectly, since they are usually fabricated of brass or similar metal that can be bent easily. The risk of such damage is likely higher with beginning users. Although there is no direct evidence to support the view that pseudo-astrolabes were used as teaching aids, it is possible to conclude that some may have been used for this purpose, given the demonstrated necessity of instruction in astronomy.

Closely related to the astrolabe is the device known as a *planetary equatorium* (Price

& Wilson, 1955). Although the origins of this device may be ancient, it seems to have gained both widespread acceptance and extensive use throughout the Islamic world during the mediæval period (Price & Wilson). An equatorium, which is usually constructed in a manner similar to an astrolabe, consists of a number of circular concentric plates or wheels which can represent the planets, the moon or other specific celestial bodies. The smaller plates are arranged to fit onto a pin located on the larger housing plate. The arrangement of the parts is similar to the assembly of the parts of an astrolabe. The centre of the array is intended to represent the earth, so the movement of the celestial bodies reflect a belief in a geocentric cosmos. The circumference of the housing plate is usually inscribed or painted with several scales, of which one was usually the zodiac, to indicate the precise location of the objects in the cosmos. Pointers attached to the smaller plates or wheels served to indicate the relative position of the objects they represented. Equatoria can be constructed of a variety of material including metal and wood. Depending upon how it is constructed, an equatorium can show the movement of only one planet, or it can show the movement of several planets as well as the phases of the moon (Price & Wilson, 1955). Price and Wilson (1955) note that equatoria could have been used for demonstrational purposes as well as for computation. If equatoria were used for demonstrations, then there can be little doubt that they were intended to be teaching aids. One of the first accounts of an equatorium in the Islamic world dates from the beginning of the eleventh century A.D. Although the account describes the construction of the equatorium, it is not clear whether it was intended as a calculating device for devising astronomical tables, or whether it was intended to be used as a teaching aid (Price & Wilson, 1955). The appearance of equatoria in the West, beginning in the thirteenth century A.D., and their use as teaching aids at that time, suggests that it is likely that they were also used as teaching aids in the Islamic world. The existence of other devices that appear to have been designed for instructional purposes may indicate that the Muslims did recognize that certain devices could be used to demonstrate complex abstract concepts that were often difficult to teach by means of lecturing.

Astrolabic teaching machines

By the beginning of the thirteenth century A.D., some astrolabes were being produced which contain a gear train that could be altered by movement of the alidade (King & Millburn, 1978). The gear train moved either plates or pointers on the reverse side of the astrolabe. These indicators show either the phases of the moon or the relative position of particular planets or other celestial bodies. It seems likely that the primary purpose of geared astrolabes was for the proper determination of religious occasions that were related to lunar cycles (King & Millburn). It is possible, however, that geared astrolabes were also used as teaching aids and possibly as teaching machines. One could, for example, use a geared astrolabe to demonstrate relative motion of celestial bodies in a concrete manner. If one possessed enough background information about the operation of the astrolabe, including the significance of the dials and scales, the geared astrolabe could also function as a teaching machine. In respect to the definition of teaching machines presented in the previous chapter, the *input* would consist of the user aligning the alidade to a known celestial object. The *transformation* would be the movement of the gear train and the consequent movement of the indicating dials or plates, and the *feedback* would consist of a new indication on the dials or plates, which would signify that the position of one celestial body would be judged relative to other celestial bodies sighted. A visual check of the position of the other celestial bodies, if they were within the visible cosmos at the time, would prove that the information presented by the machine was true. In this manner, a geared astrolabe could be used as a teaching machine. There is no evidence available to indicate whether or not geared astrolabes were used for this purpose in the Islamic world.

Mechanical planetaria

There is some evidence, although not from sources of the time, to indicate that some variety of mechanical planetarium was known to the Islamic world. Trithemius (1462-1516), the abbot of the monastery of Saint Jakob in Würzburg, describes an elaborate and expensive *astronomical machine* that was fabricated by the Arab geographer Edrisi, which was presented by the Sultan of Egypt to Frederick II, Holy Roman Emperor, in 1232 (Lacroix, 1877, pp. 200-212; King & Millburn, 1978). Trithemius' description is vague, so there is controversy about what the device actually was, and whether or not it was actually constructed. The description given suggests a device that was similar in design to Archimedes' spheres, with a central sphere representing the earth, and smaller spheres suspended by some means about the central sphere representing particular celestial bodies. While it is assumed that the smaller spheres revolved about the central sphere, their movement was apparently driven by a weight (King & Millburn, 1978). If this description is accurate, then the device cannot be considered a teaching machine, but a teaching aid, since there is no user input except raising the weight and releasing it. It is also unlikely that Edrisi's device was used extensively as a teaching aid, since it was fabricated of precious metals and gems. It may be asked whether or not less expensive versions of this device were produced in the Islamic world for instructional purposes. *Prima facie,* it would seem likely that this was so. A lack of evidence, however, prevents this question from being answered unequivocally.

It is apparent that astronomical devices were either improved or invented in the Islamic world during the mediæval period. Although it is not certain whether or not these devices were used as teaching aids and teaching machines, evidence will be presented in later sections to show that the knowledge of such astronomical devices spread to other areas of the world at various times throughout the mediæval period and that many of the devices were used as teaching aids and as teaching machines. An investigation, to ascertain whether or not teaching machines in other areas of instruction were used in the Islamic world during the mediæval period, might provide an indication of prevalent views towards instructional devices.

Geomancy instructor

The art of geomancy (a method of fortune telling) was practiced in the Islamic world before the fourteenth century A.D. In order for one to tell a fortune through geomantic means, one had to possess a knowledge of certain patterns of dots which comprised geomantic figures. The way in which these geomantic figures were generated and connected determined the prediction of the individual's fortune (Savage-Smith & Smith, 1980). By the time of the thirteenth century, geomancy had so developed that considerable skill was required both to generate the geomantic figures and to connect them in such a way as to present a plausible fortune. A single example exists of a contrivance constructed in 1241 or 1242 A.D., which contains a number of rotatable circular dials and quadrant indicators (Savage-Smith & Smith, 1980).

The device, which is now housed in the British Museum, is composed largely of brass. The apparatus, consisting of two rectangular plates which house the internal workings, measures 337 mm in length, by 250 mm in height overall (Savage-Smith & Smith, 1980, p. 17). The surface of the front plate contains 19 small openings which reveal a segment of 19 independent dials located behind, each decorated with geomantic symbols. The front plate also contains one semi-circular opening which reveals one-half of a larger dial. Small pointer knobs also protrude beneath each of the openings, which enable the user to rotate the dials beneath the openings of the plate. Engravings on the plate around each knob serve to indicate the relative position of each dial. Arabic inscriptions in each of the engravings indicate to the user what the selected pattern of dots represent. The upper right-hand corner of the plate contains four quarter-circular openings which reveal quadrant strips, also decorated with geomantic symbols (Savage-Smith & Smith, 1980, pp. 16-17). Small handles on each quadrant strip enable the user to place each strip at the desired position. All four quadrant strips are decorated with geomantic symbols in a similar manner to the dials. Figure 12 (after example in the British Museum, London) shows the general appearance of the device. For the sake of clarity, all of the inscriptions have been omitted.

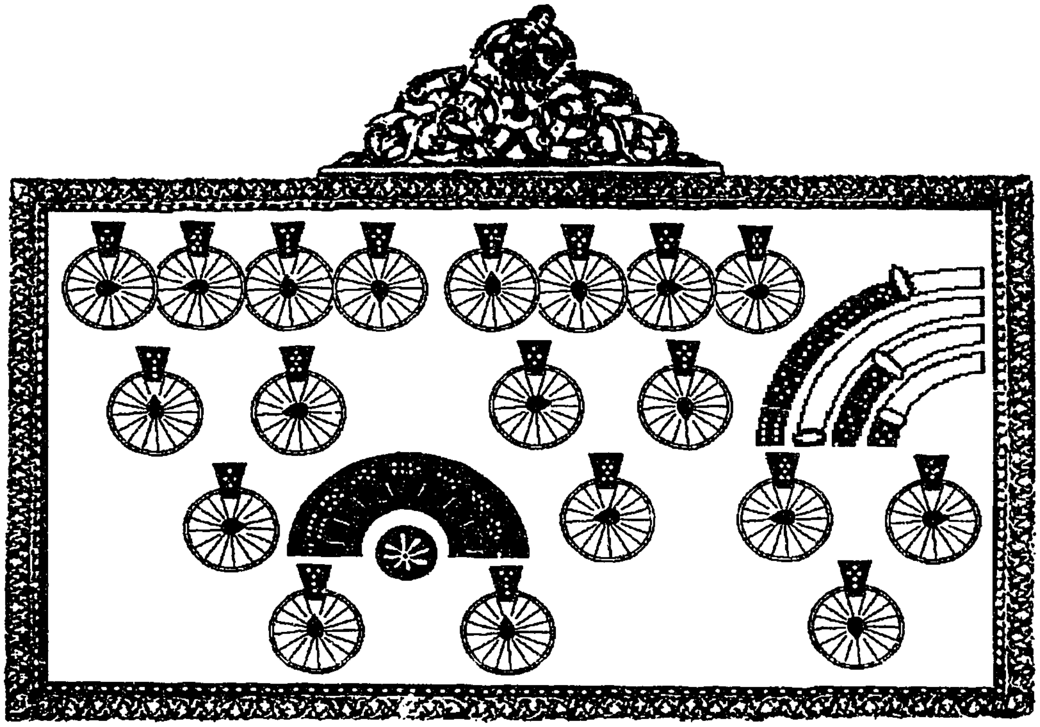


Figure 12. Islamic instructor for geomancy

At first glance it might appear that this device is not a teaching machine at all, but that it is a calculating device for obtaining geomantic symbols by users who were familiar with its operation. This notion is shared by Savage-Smith and Smith (1980) who state, "the absence of instruction on how the figures in the various houses are derived is significant, for it clearly indicates that the tablet was intended for someone already acquainted with the process of casting a geomantic tableau" (p. 60). It has been shown in the previous chapter that particular teaching machines could be used only when the intended user had received some prior instruction. Examples include Archimedes' and Posidonius' planetaria teaching machines. It may be asked if there are any indications that infer that the Islamic geomancy device was a teaching machine? The answer is yes. It was mentioned previously that the device was embellished with many inscriptions. While many of them simply indicate what a position of a dial referred to, there are also some inscriptions which seem to be instructive rather than descriptive. One inscription in particular, located beneath the large dial, implies that the device was intended to be used as a teaching machine, "from my intricacies there comes about perception superior to books concerned with the art [of geomancy]" (in Savage-Smith & Smith, 1980, p. 35). Another inscription, this one located above the large dial states, "we have established this circle so that you might learn from it the correspondences of the forms of the figures with the forms of the lunar mansions, rising and setting" (in Savage-Smith & Smith, 1980, p. 29). A similar inscription located near the four quadrant strips states, "we have placed these arcs [quadrant strips] in order to generate the [geomantic] figures, and so you [will examine] what appears next to the separating line at the point of visibility, and from them you generate the Mothers [a part of the connection of the individual geomantic figures]" (in Savage-Smith & Smith, 1980, p. 29).

It is apparent, from the above quotes, that the contrivance could have been used as a teaching machine. The *input* would consist of the user turning the knob of a dial or quadrant strip, guided by his/her background knowledge of geomancy as well as the instructions engraved on the device. The *transformation* would consist of the internal parts moving, and the *feedback* would be the geomantic pattern visible in the opening of the dial or dials. Thus, without an extensive knowledge of geomancy, it would be possible for a user to cast a geomantic tableau of an individual and to learn simultaneously much of the process involved. With repeated practice, it is also possible that the user would gain sufficient knowledge to be able to perform the casting of a geomantic tableau without the assistance of the device.

It may be asked whether this type of apparatus was used widely in the Islamic world? The example in the British Museum is thought to be the only one of its kind in existence. In addition, the materials used for the device suggest that it was expensive to construct. As well as ornate arabesque details, most of the inscriptions are inlaid with gold and silver (Savage-Smith & Smith, 1980). Although copies similar to the surviving example likely were not produced in large quantities, it would have been possible for copies to have been constructed using materials that were less expensive. Apart from the factor of cost, geomancy was considered, at best, as being on the periphery of magic. It seems that during the thirteenth century there was a tolerant attitude towards occult activities such a geomancy (Savage-Smith & Smith, 1980). It also seems likely that when Islamic fundamentalism took hold by the fourteenth century, there was little tolerance of devices intended for the instruction of practices considered outside the approved tenets of Islam.

While most uses of instructional devices in the Islamic world appear to have been either developments or refinements of ancient devices, the existence of the geomancy teaching machine, as well as the record in the West of other types of teaching machines either derived from the Islamic world or induced by its practices, indicates that the pedagogical merits of using teaching aids and teaching machines were recognized and continued during the early mediæval period. While it was stated at the outset of this chapter that the mediæval world could be considered as four distinct divisions, there was limited communication between some of the divisions. One such connection, between the Islamic world and the West, may have provided the rudiments for an early Western educational innovator.

Developments in the west to 1200 A.D.

Gerbert's pedagogical philosophy

Sylvester II, the first Frenchman to become pope, died in 1003 (Darlington, 1947). Gerbert of Aurillac, as he was known before his election to the papacy, was noted for his earlier work as a teacher; a teacher who devised and used both teaching aids and teaching machines. His chronicler, Richer (ca. 1000), writing about Gerbert's teaching states, "He broke with all tradition in his devising of charts, models, and instruments for demonstration to his students and for handling by them..." (in Lattin, 1961, p. 18). Richer's comments indicate that the use of teaching aids and teaching machines had been neglected or ignored, since their use was contrary to an established tradition. This does not necessarily mean that the use of teaching aids or teaching machines in academic subjects was known and found to be undesirable. Richer's remarks imply that articles as simple as charts were no longer considered as being teaching aids.

Gerbert's teaching aids

The use of teaching aids to provide tangible representations of abstract concepts figured prominently in Gerbert's approach to pedagogy. In a letter written in 999, Gerbert included a diagram to illustrate the calculation of the area of a triangle (Lattin, 1961). To assist his instruction of rhetoric, Gerbert devised an elaborate parchment chart that summarized the important rules. He states,

> I drew up a diagram of rhetoric on twenty-six leaves of parchment sewed together, and forming in all two columns side by side each of thirteen leaves. It is without doubt a device admirably adapted for the ignorant and useful to the studious scholars in order to help them understand subtle and obscure rules of rhetoric and to fix these in their memory. (Gerbert, 986, in Darlington, 1947, p. 472)

If charts and other teaching aids were considered unsuitable for educative purposes, rather than simply being ignored, then it follows that Gerbert would have been criticized by his contemporaries for employing such methods. In fact the opposite was the case. In several of his letters, Gerbert acknowledges praise and kind remarks directed towards his use of teaching aids (Lattin, 1961).

More elaborate apparatus, such as the abacus, had also been forgotten as being useful teaching aids. In a letter from 980, Gerbert describes an abacus he designed and had constructed that could show multiplication and division in a tangible manner, so that an abstract concept did not have to be grasped initially (Lattin, 1961). The abacus consisted of a large board made by a shield maker. It was divided into 27 columns lengthwise. Each column had several symbols placed in it, probably painted, which represented numbers. Special horn characters were then placed on the symbols to perform either multiplication or division (Lattin, 1961). By using the abacus in conjunction with a lecture, it would have served as a teaching aid. It is likely that Gerbert's abacus was also used as a calculating device.

Gerbert's teaching aids for astronomy

Instruction in astronomy was still considered important by some scholars in the West during the mediæval period, since astronomy was one component of the *quadrivium*, a four-part curriculum that was adopted in Roman times and which prevailed in the West during the mediæval period. Astronomy was also important for the accurate determination of Easter and other occasions significant to the early Christian church. Gerbert employed both teaching aids and teaching machines in conjunction with astronomy and he also produced astronomical teaching aids for other individuals (Gerbert, 989, in Lattin, 1961). One of the most popular of his devices was his design for a celestial globe. It should be recalled that one of the first celestial globes was produced by Thales of Miletus about 550 B.C. Gerbert's celestial globes consisted of turned wooden spheres that were covered with horsehide. Constellations and other celestial bodies were then painted on the surface in a variety of colours (Gerbert, 989, in Lattin, 1961). Celestial spheres were used primarily as adjuncts to lectures. Their use would have been similar to that of Thales of Miletus's globe, fabricated at about 550 B.C.: a teaching aid. Gerbert's *reinvention of the wheel* did not stop there.

It should be recalled that Cicero stated that Thales of Miletus's globe had a major drawback; it could not show movement of celestial bodies. In addition, it was also emphasized that in order for one to understand the significance of the marks on the globe, one first had to have some knowledge of the cosmos and an understanding of what the marks were supposed to represent. The mechanical planetaria devised by Archimedes and by Posidonius of Rhodes had overcome some of the problems associated with solid spheres, since the relative motion of the individual celestial bodies was shown. While it has been argued that both Archimedes' and Posidonius' devices may have been used as teaching machines (see Chapter II), their success as teaching machines was dependent upon the user possessing a concept of what the cosmos was. It is evident that the knowledge of these ancient devices had been forgotten by Gerbert's time, since he both addressed and dealt with the same problems that had faced Archimedes almost 1,500 years earlier.

Gerbert realized that, while one could paint lines or otherwise indicate paths of movement of specific celestial bodies on a solid sphere, it would be difficult for a student to gain a knowledge of the relative position of such bodies in the heavens. To overcome this problem, Gerbert first constructed a specialized armillary sphere (Richer, 999, 3.52). An armillary sphere is a device that consists usually of a number of intersecting and concentric circular rings arranged in such a way that their circumferences form the outline of a sphere. In most instances, a small sphere, representing the earth, is supported at the centre of the array. The rings represent the trajectories of particular celestial bodies and may also represent a horizon and the location of the zodiac. There is, usually, some means of aligning the apparatus to the pole star or some other specific celestial body (King & Millburn, 1978). Armillary spheres, which were known to and used by the Egyptian astronomer Ptolemy in the first century A.D., could be designed for different purposes. The type of construction determined what the sphere could be used for. Armillary spheres were primarily used for determining the equinoxes, as well as for locating the position of a particular celestial body accurately in relation to the pole star or some other known celestial body. The latter feature meant that armillary spheres could also be used for navigational purposes (King & Millburn, 1978). Gerbert thought that by adding additional rings to an armillary sphere one could illustrate the orbits or the paths of the known planets (Richer, 999, 3.52). Richer (999) notes that this device was intended to be a teaching aid solely, as "he [Gerbert] figured with an extraordinary art the orbits traversed by the planets, whose paths and heights he demonstrated perfectly to his pupils, as well as their respective distances"(3. 52). A problem remained in using this teaching aid; although it was a useful adjunct to a lecture on the planets, it was not possible to relate directly the material learned in the lectures to actual astronomical observations. This problem was especially pronounced in instruction about constellations.

Gerbert's teaching machine

While it was comparatively easy, through the use of teaching aids, to show a class or an individual student what the constellations were supposed to look like, it was quite another matter for a student to go outside and actually identify specific star patterns as particular constellations. Bearing in mind this problem of the transfer of learning, Gerbert designed another sort of armillary sphere which he intended to be used as a teaching machine. Richer (999) recounts,

> He made yet another sphere composed of circles, in the interior of which he placed no circles [it was empty]; but he fashioned above, on iron and copper wires, the forms of the constellations. For an axis he used a tube through which one looked at the north pole [he probably meant the pole star], and when one looked at this pole the machine corresponded to the sky and all the stars corresponded to the marks of the sphere. This machine was so miraculous that even those who were ignorant of the science [astronomy], if a single constellation were known to them on the sphere they could find the others themselves, and that without the aid of a teacher. (4.52)

Although no illustration of the apparatus is known to exist, it probably resembled an armillary sphere with wires attached to it which supported metal silhouettes or outlines of particular constellations. It is also likely that the apparatus was mounted on some variety of tall vertical shaft, so that the user would have to look up through the apparatus in order to see the stars which the silhouettes or outlines touched or obscured. In addition to the machine's teaching the user the locations of particular constellations, it would also show the user that the stars appeared to move through the cosmos. This would be realized after a short period of time, when the movement of the earth would be sufficient to create a noticeable misalignment between the machine and the constellations. The perceived misalignment would teach the user that either the heavens or the earth had moved. In order to regain the use of the apparatus to indicate constellations, the user would have to re-align the machine, further indication that either the heavens or the earth had moved.

Gerbert's constellation teaching machine was not as mechanically elaborate or as abstract in operation as the planetaria designed by Archimedes, since there was a direct link between Gerbert's machine and what was actually in the cosmos. Gerbert's device was, nevertheless, a teaching machine. The *input* consisted of the user aligning the device to the pole star and also aligning a known silhouette or outline to a known constellation. Both the *transformation* and the *feedback* were in two parts. First, the positioning of the initial silhouette or outline meant that the others would be aligned with their constellations. This action results in the user obtaining feedback by associating those stars outlined or obscured by the silhouettes with the particular constellation that each silhouette or outline represents. Second, the passage of time transforms the apparatus from alignment to misalignment. This action reveals that either the earth or the stars are not stationary, but are moving in a single direction. It is important to consider that in order to use Gerbert's device as a teaching machine, the user would have to possess knowledge of where the pole star was as well as being able to identify one constellation. These provisos indicate that the user must receive some instruction in astronomy prior to being allowed to use the teaching machine.

Gerbert's work both as a teacher and as a designer of teaching aids and teaching machines came to an end upon his election as Pope Sylvester II, in 999 (Richer, 999, 4). It is reasonable to ask what sort of training Gerbert received that may have influenced his inclination to develop teaching machines and teaching aids, given the established tradition in the mediæval West of not using either. It seems that part of Gerbert's education took place in Spain, where he was taught both mathematics and astronomy (Hock, ca. 1850, p. 113). Spain, at that time, was under the influence of the Islamic world, and it is likely that Gerbert was taught a curriculum that included subjects considered important in the Islamic world, such as mathematics, but which were not considered important in the West (Hock, ca. 1850; Darlington, 1947). Gerbert's possible connection with Muslims and his subsequent use of teaching aids and teaching machines led to serious consequences after his death in 1003.

Significance of Gerbert's devices

It was mentioned in a previous section that Gerbert did not receive much criticism for his use of teaching aids and teaching machines during his lifetime; in fact he was given considerable praise. It also seems that other teachers employed teaching aids and teaching machines based on his designs (Darlington, 1947). Stevenson (1921) notes that Notker Labeo, a teacher at the monastic school of St. Gallen in Germany, employed celestial spheres for astronomical instruction (p. 38). Labeo, who lived from 950 to 1022, may not have obtained his knowledge of teaching aids from Gerbert, but this is doubtful, given that Gerbert's work was well known and widely accepted before his election as pope.

The apparent acceptance and adoption of Gerbert's methods were short-lived. Less than 100 years after the death of Sylvester II, written accounts appeared which accused him of having been taught by Muslims to practice *black magic* (Hock, ca. 1850). Accusing Sylvester of entering into an agreement with the devil, many critics also implied that his *devices* were nothing more than magical objects which had enabled Sylvester to confound his opponents and adversaries. One account, written by William of

Malmesbury about 1150, describes crudely the abacus designed by Sylvester. William concludes that the device could be nothing but a special talisman that was endowed with powers which enabled Sylvester to use supernatural and illicit forces to obtain superiority over his rivals, to the extent of his election to the papacy. William continued by stating that the knowledge to build such a diabolical device came from Sylvester's education in Spain (Hock, ca. 1850). It is apparent from such accounts that the true purpose of Sylvester's teaching aids and teaching machines was obscured by this time, and that the use of such instructional devices was not widespread. It also seems that a lack of *social acceptability* in the West seriously restricted the use of any such instructional devices, since they were seen as instruments of the devil, rather than as adjuncts to or instruments of instruction.

Although it has been shown that Gerbert's devices were sound pedagogically and that some of his contemporaries also realized their merits, it seems that the learning theories that the devices embodied, the learning of a concept by the observation of a tangible example or the comparison of a tangible example to aspects of nature, were forgotten or obscured. There are several possible ways to explain why this occurred. It may be that the pedagogical merits of Gerbert's devices were not understood by many educators, or it could be that most of them preferred to instruct by using traditional lecture methods without using either teaching aids or teaching machines. It may be that other considerations, namely the origins of the devices and their religious and the political ramifications, displaced their pedagogical merits. Stevenson (1921) favours the latter possibility, but he does not cite any primary sources to support his view.

Although a lack of evidence prevents a definite conclusion from being drawn about why it should be so, the condition of teaching aids and teaching machines in the West remained in a state of disorganization and limited use until the thirteenth century.

Developments in the Byzantine World

Historical antecedents

A previous section states that it is likely that the Islamic world obtained its knowledge of astronomy from the ancient world. While it is also possible that the pedagogical principle of employing instructional devices was also derived from ancient sources, it is clear that the Islamic world used instructional devices for reasons other than those followed by the ancient Greeks and Romans. Similarly, it can be shown that there was some knowledge of ancient sources in the Byzantine world during the early mediæval period. It can also be shown that there was probably some influence from the Islamic world, and that the impetus for employing particular devices as aids to instruction may also have originated with that division. Concerning the Byzantine world, there is no clear evidence to indicate whether the use of instructional devices was uninterrupted from ancient times or whether their use was the result of recent influence from the Islamic world. There is evidence, however, of at least one individual in the Byzantine world who devised and produced teaching aids to illustrate astronomical theories known from ancient sources.

Leontius Mechanicus

Leontius Mechanicus (the engineer), who wrote a treatise on the design of a celestial sphere based upon the description provided by the Roman Aratus, lived at some point in the early mediæval period. Some accounts, based upon apparent historical context, place Leontius as early as the third century A.D. (Smith, 1865). Another account (Chevalier, 1907/1960) indicates that Leontius probably lived during the sixth century A.D. A more contemporary work (Stevenson, 1921) suggests that Leontius probably lived either during the seventh or the eighth century A.D. Although it might appear too difficult to obtain a more accurate indication of when he lived, a contemporary linguistic analysis of his treatise, which has survived in an abbreviated form, suggests that Leontius probably lived during the tenth century A.D. (personal communication with Dr. R. J. Buck, January 1989). In addition to identifying a syntactic structure that is indicative of writing from the tenth century, the analysis notes the existence of at least one word of Arabic origins that was most probably unknown in the Byzantine world before the tenth century. If the linguistic analysis is correct, Leontius' work with teaching aids may have been roughly contemporary with the similar work of Gerbert (Sylvester II) in the West. While it is possible that the two men existed at roughly the same time, their instructional devices were very different.

Leontius' celestial spheres

Leontius, unlike Gerbert, was not a teacher, and in his treatise on the construction of celestial spheres he indicates that he first produced a prototype for Elpidios the scholar (Leontius, 1., in Maass, 1898/1958, trans. R. J. Buck, 1989). While it is not revealed whether or not Elpidios was a teacher, Leontius indicates that the information placed on the celestial sphere was based on the writings of the Roman Aratus as well as on Ptolomeic theory (Leontius, 2., in Maass, 1898/1958, trans. R. J. Buck, 1989). Leontius also states that celestial spheres are not particularly useful for navigation,

> for those engaged in navigating are accustomed to observe the position of the stars not precisely through mechanical devices, but roughly through a quick upward glance. Thus the sphere as constructed is not really useful for the precise truth, but rather for getting a grasp of the Aratean concepts [of the cosmos]. (Leontius, 2., in Maass, 1898/1958, trans. R. J. Buck, 1989)

It is reasonable to conclude from the above quote, that the celestial spheres produced by Leontius were intended to be used as teaching aids.

Besides describing the theory behind such celestial spheres, Leontius also provides detailed instructions on how to prepare spheres, so that they reflect Aratean cosmic theory accurately. His instructions assume that one has already produced a sphere. While Leontius' instructions are specific to wooden spheres, he indicates that other materials may be used instead (Leontius, 5., in Maass, 1898/1958, trans. R. J. Buck, 1989). Leontius intended that the information be placed directly on to the sphere, unlike the celestial spheres of Gerbert (Sylvester II), who painted the information onto a horse-hide covering attached to the sphere. To paint directly on a wooden sphere, Leontius recommends the application of a coating of either gypsum or wax, to fill any imperfections in its surface. This coating would be omitted in the case of a sphere composed of other materials such as bronze or stone (Leontius, 5., in Maass, 1898/1958, trans. R. J. Buck, 1989). The next steps are to paint the sphere a dark colour, then paint circles and specific celestial bodies on the surface as well as driving a pin into the sphere, by means of which one could attach a meridional ring (Leontius, 4.-5., in Maass, 1898/1958, trans. R. J. Buck, 1989). For the first step in painting, Leontius suggests the use of a dark-blue shade he calls *lazourian* (Leontius, 5., in Maass, 1898/1958, trans. R. J. Buck, 1989). Leontius' use of that word is significant, since its origin is Arabic (personal communication with Dr. R. J. Buck, January 1989). Although Leontius states that his particular celestial spheres are based on Aratean and Ptolomeic theories, he does not indicate where he obtained the idea of producing a celestial sphere for use as a teaching aid.

Leontius refers to other spheres "now in current use" as not properly corresponding either to Aratean or Ptolomeic theories (Leontius, 2., in Maass, 1898/1958, trans. R. J. Buck, 1989). Leontius does not provide any additional information about these spheres, so we do not know how long ago the notion of making celestial spheres and using them as teaching aids had occurred within the Byzantine world. His desire to describe the construction of a sphere that would reflect Aratean theory accurately, as well as his use of a word of Arabic origin, implies the existence of knowledge derived from the Islamic world. If this is so, then it is possible that the concept of using celestial spheres as teaching aids also came from the Islamic world within the lifetime of Leontius. While there is insufficient evidence to support or refute this notion unequivocally, it is clear that celestial spheres were used as teaching aids in the Byzantine world by the time of Leontius.

Developments in the East

Status of teaching aids

It has been noted in previous sections of this chapter that a paucity of information makes it difficult to ascertain whether a particular device observed in different areas means that the idea for the device originated from a common source, or whether the device was developed independently. This same principle may be applied to the problem of whether any astronomical devices in China were ever used as teaching aids. Needham and Ling (1959) state that Chinese astronomy may have originated in ancient times, perhaps independently of outside influence. Later developments, however, appear to have been influenced by the ideas of other areas and cultures. By the seventh century A.D., knowledge of Hellenistic astronomical ideas seem to have reached China (Needham & Ling, 1959).

While it may be argued that the idea of using objects as teaching aids also came from other areas, their use for astronomy within China was restricted for many years. Unlike many other heads of state in the East, West or within the Islamic world, the Emperor of China included among his responsibilities the interpretation of the meanings and messages presented by the position and the order of celestial bodies (Needham & Ling, 1959). From this knowledge, the emperor could predict practical events such as the coming of spring or the arrival of the monsoon season. Such predictions were important, since Chinese culture was largely agrarian. Although the emperor could and did share his duties with assistants (astronomers among others) the practice of astronomy by the general public was not only discouraged, but the dissemination of astronomical information by imperial astronomers was prohibited by edict as early as 840 A.D. This edict remained in force until the seventeenth century, but it seems not to have always been enforced rigorously, since there is evidence of Islamic influence, as well of later Western influence from the Jesuits, about 1600 (Needham & Ling, 1959).

It might appear, from this description, that there was no *social acceptability* for the use of astronomical teaching aids in China. This impression is not entirely correct. Not only did new court astronomers have to be trained, but emperors and their heirs had to be acquainted with the traditional and approved ways of observing and interpreting the cosmos (Lattin, 1969). Although the use of teaching aids for astronomy was restricted, there is evidence to show that they were more widely used in other subjects.

Chinese astronomical teaching aids

One of the earliest astronomical devices known to have been used as a teaching aid in China was the armillary sphere. Although some armillary spheres were intended for observational purposes only, others seem to have been constructed solely for calculation and demonstration (Needham & Ling, 1959). The existence of Chinese armillary spheres may date to the late first century B.C., but it is not clear whether or not these spheres were used as teaching aids. It is also not clear whether the knowledge required to produce armillary spheres came from Hellenistic sources or was developed locally.

The first armillary sphere purported to be produced for demonstrational purposes was made about 125 A.D. by Chang Hêng (Needham & Ling, 1959). The configuration and the appearance of these early demonstrational armillary spheres is not certain, but it seems likely that they resembled known designs from the third century A.D. Later designs consist of an armillary sphere sunk into a square box. In this design, the earth was represented as the box, since it was widely believed that the earth comprised a cube. The sphere represented the heavens placed on the surface, so that only half of it was visible, similar in appearance to a dome. While it is likely that early examples of this type of demonstrational armillary were fixed in one position, most later versions could be rotated and were powered by some variety of water-driven mechanism (Needham & Ling, 1959). Apart from these developments, the demonstrational armillary sphere remained unchanged for over a millennium until the arrival of Islamic influence in the thirteenth century (Needham & Ling).

Celestial spheres were also used as teaching aids in conjunction with astronomical instruction of a select few. Unlike demonstrational armillary spheres, which predate the mediæval period, celestial spheres do not appear to have existed in China before the fifth century A.D. (Needham & Ling, 1959). It seems that demonstrational celestial spheres were used in the same manner as demonstrational armillary spheres. Most celestial spheres were arranged so that they were set in a cubic frame representing the earth. Figure 13 (after drawing in *Hsin I Hsiang Fa Yao,* 1092) depicts a typical arrangement of a Chinese celestial sphere.

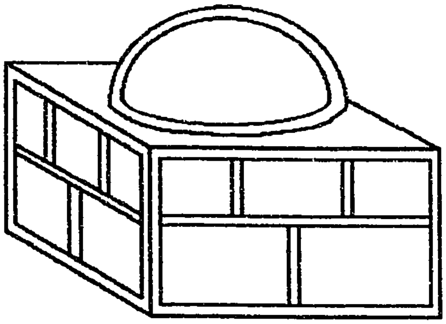


Figure 13. Typical appearance of Chinese celestial sphere

Mechanized versions were produced, the most elaborate model known was one which comprised part of an enormous water-driven astronomical clock designed by Su Sung which was completed in 1090 A.D. for presentation to the emperor (Needham & Ling, 1959). Parts of the astronomical clock, such as the mechanized armillary sphere, were intended for observatory work. It seems likely that the mechanized celestial sphere, which was not designed for observational purposes, was used as a teaching aid. Sufficient information is lacking to permit a definite conclusion from being drawn, however.

Apart from the introduction of Islamic influence in the thirteenth century, when Arab astronomers were employed by the Chinese court, the development of teaching aids for astronomy in China and most of the countries under its influence remained unchanged until the arrival of the Jesuits about 1600 (Needham & Ling, 1959). The same cannot be said about one notable teaching aid for arithmetic, the abacus.

Abacus

Although there are some individuals who believe that the abacus originated in China, the available evidence indicates that this belief is wrong. Williams (1985) states that the abacus was known to the ancient world during Hellenistic times, and that it could have had earlier origins. Though it is not possible to indicate precisely when knowledge of the abacus reached China, it was certainly well after the birth of Christ. The earliest unequivocal evidence is dated to the thirteenth century A.D. (Williams, 1985). While it is likely that the Chinese used the abacus primarily as an aid to calculation, it seems probable that they also used it to instruct the rudiments of arithmetic in much the same manner as the ancient Romans.

It should be recalled that the design of ancient abaci is of tablets or plates that can accommodate some form of counter. One problem with such a design is that the counters can be easily disturbed and lost. A notable improvement to the abacus consisted of making the counters from beads which could be strung onto several stiff wires that could, in turn, be secured in a frame. This design of abacus, widely known as the wire-and-bead type, largely eliminated the problem of losing counters (Williams, 1985). It is not known whether the Chinese developed this improvement to the abacus, or whether the improvement had been made in the Islamic world. It should be recalled, from an earlier section concerned with teaching aids used by Gerbert (Sylvester II), that he seems to have been unaware of wire-and-bead abaci. It is likely, given his innovations with other apparatus and his likely connection with the Islamic world, that if the wire-and-bead abacus did exist, Gerbert would have used it as a teaching aid. Be that as it may, the Chinese appear to have used the bead-frame abacus as a teaching aid as well as for an aid to calculation (Williams, 1985).

While there is little specific evidence to support the idea that the abacus was used initially as a teaching aid in China, some modern accounts note that, until recently, basic addition and subtraction were taught in Chinese schools with the aid of a special demonstrational abacus (Leavens, 1920). It is likely, therefore, that this modern use reflects a long tradition in China of using the abacus as a teaching aid for arithmetic.

Demonstrational models, which may still be used in some Chinese schools, are much larger than the ordinary abacus. While the rods supporting the beads in smaller abaci can be made of metal, most demonstrational abaci seem to use wooden rods for this purpose. The reason for this is to permit bristles to be inserted into the circumference of the rods. The bristles tend to hold the beads in particular positions. The teacher may use this demonstrational abacus variously to teach the concepts or principles of addition and subtraction as well as to teach the use of the abacus as a calculating device (Leavens, 1920). If an abacus were used to teach the principles of arithmetic, then it is being used as a *teaching aid,* while a lesson on the use of the abacus as a calculator would make it a *necessary tool.*

Other Chinese teaching aids

It is likely, given the connection between the Islamic world and the Chinese, that other devices that were used as teaching aids in the Islamic world, such as the astrolabe, were also used for the same purpose in China. No evidence appears to exist of astrolabes being used as teaching aids in China, however. This lack of evidence does not mean that the astrolabe was not used as a teaching aid. It should be recalled that the dissemination of knowledge related to astronomy as well as the practice of astronomy was severely restricted in China because of an Imperial edict (Needham & Ling, 1959). Knowledge of the astrolabe did spread to other areas of the East, however.

Hartner (1965) notes that by the beginning of the thirteenth century A.D., the astrolabe was being used in India. Given this evidence of its use in the East, coupled with the knowledge that Islamic astronomers were hired by the Chinese court, it seems likely that the astrolabe was known to the Chinese by the thirteenth century A.D. While it is not known definitely that the astrolabe was used as a teaching aid, it is logical to assume that it was used for that purpose, given that the Islamic world did use it as a teaching aid and that Eastern knowledge of the astrolabe came from the Islamic world. The pedagogical approach of using teaching aids does not seem to have been a matter of controversy in China, given the apparent use of the abacus as a teaching aid. What was probably the greatest factor that restricted the use of teaching aids in China was the connection between them and instruction in forbidden subjects, most notably astronomy and astrology.

It seems, from what has been presented, that teaching machines were not used in mediæval China, but teaching aids were. It also seems that the use of teaching aids was, in some areas such as in astronomy, restricted by social considerations. While the pedagogical concepts of using teaching aids for instruction were accepted, given the continued use of teaching aids to instruct new astronomers as well as emperors, little innovation with teaching aids appears to have occurred. Innovation did occur in the West during the latter portion of the mediæval period.

Developments in the West from 1200 A.D.

Astrolabes and equatoria

A previous section dealing with developments in the West to 1200 A.D., notes that the use of both teaching machines and teaching aids was not widespread before the thirteenth century, primarily because of social factors, not pedagogical considerations. While Gerbert (Sylvester II) may have obtained knowledge of certain instructional devices from the Islamic world, widespread acceptance of such devices in the West after his death in 1003 was not sustained because of the association of the devices with Islam and with the possible practice of black magic. Although some individuals may have continued to shun anything originating from the Islamic world because of religious differences, it seems that by the thirteenth century the practical aspects of certain devices outweighed the criterion of origin. Hartner (1965) notes that the general use of the astrolabe for navigational and computational purposes can be traced to the thirteenth century, when the availability of Latin translations of Islamic works on the astrolabe increased. Thomson (1978) states that the first works translated from the Arabic appeared during the twelfth century, but that the most popular works, which were copied widely, were not translated until the latter half of that century. King and Millburn (1978) claim that Gerbert (Sylvester II) may have known about the astrolabe. While this claim may be accurate, there is no evidence to indicate that Gerbert actually used the astrolabe as a teaching aid. Also, there is no evidence to show that knowledge of the astrolabe as a teaching aid existed in the West for some time after his death.

In addition to the evidence that the astrolabe saw widespread use in the West beginning in the thirteenth century, new works on the uses and the design of the astrolabe were also written in the West at this time (Kennedy, 1970). One of the most notable was a two-part work attributed to Geoffrey Chaucer, on the design and some of the uses of an astrolabe and an equatorium. The first part, *A treatise on the astrolabe*, believed to have been written in 1391, was intended for the education of his son "littel Lowys" [little Lewis] (Price & Wilson, 1955).

At least one illustration indicates that the astrolabe was used as a teaching aid during this period. Figure 14 (after a thirteenth century miniature from the *Breviary* of St. Louis, in Lacroix, 1877, p. 99) depicts a cleric giving a lesson using an astrolabe.
It is likely that the astrolabe was used as a teaching aid in conjunction with instruction about measurement, both terrestrial and celestial, and was also a demonstrational tool to show relative motion among celestial bodies.

Equatoria were mentioned previously in a section about astrolabic teaching aids in the Islamic world. While they may have been used as instructional devices in the Islamic world, there is evidence to indicate that devices based upon equatoria, if not equatoria themselves, were used for instructional purposes in the West (Price & Wilson, 1955). Although most written works of the time do not state explicitly for what the devices are to be used, it is apparent from the descriptions on their construction that survive that their primary purpose was the determination of planetary and solar longitudes and other specialized calculations (Kennedy, 1970). Just as they may have been employed in the Islamic world, they may also have been used in the West to demonstrate relative position and motion of specific celestial bodies.

Figure 14. Cleric giving a lesson using an astrolabe

Volvelles

Price and Wilson (1955) note the appearance of a device called a volvelle, which they contend is based upon the equatorium. Volvelles, which are frequently made of parchment and paper, are usually approximations of equatoria. Depending upon how they are designed, volvelles can be so complex that they can perform the calculations that are possible with equatoria, or they can be so simple that they can indicate only rudimentary principles of celestial motion. Price and Wilson (1955) state that many simple varieties of volvelle are found as parts of books (p. 119). They also note that these examples cannot have been used for calculation, since they lack the graduations and notations necessary. It is likely, therefore, that this simple type of volvelle was used as a teaching machine. In such instances, volvelles are used to illustrate tangibly the concepts discussed in the text (Price & Wilson). An example of this application is a volvelle that teaches in a tangible manner how the phases of the moon are caused. Such a volvelle might consist of a *moon* and a strip of black parchment or paper which represents the shadow cast by the earth when it is in between the moon and the sun. The user, by moving the representation of the sun and the moon about a fixed representation of the earth (input) will cause the apparatus to simulate in a crude manner, the means by which the phases of the moon occur. The transformation would be the black paper or parchment obscuring the representation of the moon. The instructive feedback to the user would be the concrete depiction that it is the earth's shadow that obscures the moon by degrees. Figure 15 depicts the possible appearance of a volvelle designed to teach the principle that the phases of the moon are caused by the earth's shadow.

Although a volvelle in this exact configuration may not have been produced, examples were designed to demonstrate similar principles (Price & Wilson, 1955, p. 119; King & Millburn, 1978, p. 19). While the content is inaccurate, since the earth rotates

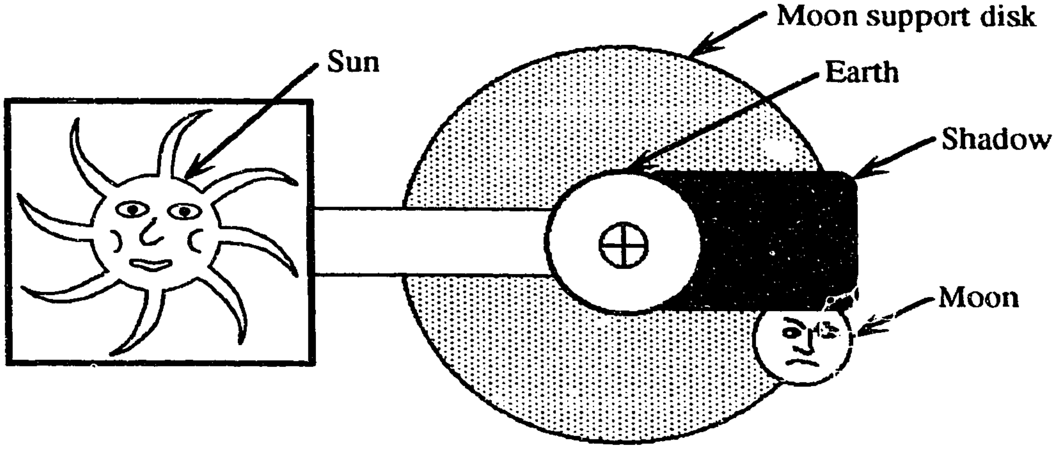


Figure 15. Volvelle to show phases of the moon

around the sun, the pedagogical principle employed is sound. A possible rationale for using such a tangible representation is to teach the concept in such a manner as to reduce the possibility of confusion. An oral presentation or a textual representation with a few fixed illustrations might not be able to convey simply and accurately the concept being taught. As well, the intention of such instruction was probably to acquaint the learner with cosmic movements, so that actual observations could be undertaken. While it is possible for a textual account to explain adequately the principles involved in a lunar eclipse, it is probably difficult to describe the individual movements of the particular celestial bodies so that the learner, especially those with little or no practical experience, can comprehend the concept clearly enough to be able to transfer what has been learned from the text to an actual and accurate observation.

While sufficient information is lacking to enable a conclusive explanation of why demonstrational volvelles were adopted, their continued use throughout the remainder of the mediæval period, past 1600 A.D., attests their usefulness as instructional devices.

Armillary spheres

It was noted in a previous section that Gerbert (Sylvester II) employed armillary spheres as teaching aids during the late tenth century. It is likely that the use of armillary spheres for such purposes was largely neglected for more than a century after his death, because such devices were equated with Islam. The later translation of Islamic works on astronomy and the widespread tolerance of them by Western society probably resulted in the re-introduction of the armillary sphere as a teaching aid. Thorndike (1949) has reproduced and annotated several works dating from the thirteenth century which are concerned with instruction in astronomical and cosmic theory. One work in particular, the *Sphere* by Sacrobosco, was a required text at most universities by the end of the thirteenth century (Thorndike, 1949). The work indicates that the cosmos as well as the earth are spherical, but no illustrations or cues for using teaching aids is provided. A commentary on Sacrobosco's *Sphere*, by Robertus Anglicus, provides an outline of lectures for teaching the important concepts contained in the *Sphere* (Thorndike, 1949). While the curriculum of Robertus Anglicus does attempt to simplify many abstract concepts by drawing analogies to familiar and tangible objects, an extensive number of lectures are required in order to cover all of the material. The difficulty with this approach is that verbal analogies are apt to be so vague that many students misunderstand the concepts. The use of a teaching aid could possibly diminish the likelihood of confusion on the part of the student. There are more definite indications that armillary spheres were used as teaching aids by the beginning of the thirteenth century. Several illustrations exist that depict instruction being given with the aid of an armillary sphere (Lacroix, 1877, pp. 90-91, p. 116; Lattin, 1969, p. 108). Figure 16 (after a miniature of the *Romance of the Image of the World,* in Lacroix, 1877, p. 91) depicts a monk giving a lesson and using an armillary sphere as a teaching aid.

Figure 16. Monk using an armillary sphere as a teaching aid

The table contains other instruments that likely were also used as teaching aids. Price (1954) suggests that the large circular object near the left edge is probably a variety of astrolabe, while the object in the middle is quadrant and the small cylinder on the right is a chilindre dial, all of use for instruction.

Unlike their short-lived acceptance for astronomy during the time of Gerbert (Sylvester II) such teaching aids were not only tolerated during the later mediæval period, but were widespread throughout the West. Price (1954) says that it is likely that early examples of armillary spheres intended for instructional purposes, that is, those produced during the fourteenth and the first half of the fifteenth centuries, were probably inexpensive because they were most likely produced of fragile materials such as wood. In support of his contention Price (1954) notes that depictions of such armillary spheres show the devices to be both crude in execution and much simpler in appearance than those depicted in use for astronomical calculation or observation. While it may be necessary to fabricate an armillary sphere of brass or bronze, in order to have an instrument that will be able to measure and to calculate accurately, it would be needlessly extravagant if the purpose of the device was to be a teaching aid. It is important to note, however, that the earliest known surviving example of a demonstrational armillary sphere is made of metal and dates from the middle of the fifteenth century (Price, 1954). It is unlikely that these surviving examples were used for purposes such as navigation or calculation, since they lack the necessary indicating scales and accuracy of construction found in surviving examples that were intended for such purposes.

Surviving examples, as well as depictions and citations in books, indicate that the armillary sphere as a teaching aid was accepted in the West by the thirteenth century, and its use continued beyond the end of the mediæval period (Price, 1954; Lattin, 1969). It seems likely, if one considers the brief existence of Gerbert's (Sylvester II) teaching aids for astronomy, that by 1200 the pedagogical merit of such devices was a consideration that overbore religious conviction and political motivation. Although it cannot be contended that all educators in the later mediæval period believed in the pedagogical merits of teaching aids, it can be argued that most did appreciate their use, since such teaching aids continued to be used for many years beyond the mediæval period.

Celestial and terrestrial globes

The later use in the West of celestial globes as teaching aids seems to be contemporaneous with the reappearance of the astrolabe and the armillary sphere in the same fashion. It should be recalled that Gerbert (Sylvester II) had constructed celestial spheres and had used them as teaching aids during the late tenth century. While it has been shown that knowledge of celestial globes existed in the Islamic world and was passed onto the Byzantine world, there is little evidence to support the notion that a knowledge of celestial globes as teaching aids continued in the West much after the time of Gerbert (Sylvester II). Although it is not certain exactly when demonstrational celestial globes were re-introduced in the West and accepted, it is likely that this occurred during the thirteenth century. One of the earliest accounts, dating from the late thirteenth century, was written by Giovanni Campano. He describes, like Leontius Mechanicus of the Byzantine world, the procedure for fabricating celestial globes. Campano, like Leontius, also thought the best material to use was wood (Stevenson, 1921). Additional evidence, which indicates that celestial spheres were re-introduced and accepted as teaching aids after the thirteenth century, comes from an account of the construction of a celestial sphere for the antipope John XXIII in 1410 (Poulle, 1963). While the intended purpose of the device is not stated explicitly, Poulle (1963) reports that it is likely that the sphere was intended as a teaching aid for the principles in the *Sphere* of Sacrobosco.

Terrestrial globes, which depict the continents of the earth on a sphere, do not appear until the late 1400s. It seems likely that they evolved from planar maps, which had been known from ancient times. One of the earliest known terrestrial globes was produced in 1492 by Martin Behaim of Nürnberg, Germany. Beginning with a turned wooden sphere, Behaim attached a covering of vellum which was then painted with the known continents and the various oceans (Stevenson, 1921). The rationale for placing a map on a spherical surface was probably to aid navigation as well as to illustrate how the earth could be spherical. In the manner of a celestial sphere, a terrestrial sphere could be used as a teaching aid for both geography and for visibly demonstrating the supposed configuration of the earth. Although the need for celestial globes diminished in later years, probably because astronomy was dropped as a compulsory subject by many educational institutions, terrestrial globes continue to be ubiquitous teaching aids.

Mechanical planetaria

The section dealing with mechanical planetaria in the Islamic world notes the possible existence of a small, weight-driven planetarium that was presented to the Holy Roman Emperor, Frederic II in 1232 (King & Millburn, 1978). Although it cannot be ascertained whether or not this device actually existed, there is much evidence to indicate that planetary models were being produced in the West by the beginning of the fourteenth century (Bedini & Maddison, 1966; King & Millburn, 1978). Unlike the mechanical planetaria mentioned previously, the devices produced in the West were usually large models of the cosmos that were driven by some variety of clockwork mechanism (King & Millburn). Some versions were constructed as astronomical clocks, and the dials of these examples were usually large and were displayed where they could be viewed by the public. Another version, called an *astrarium*, which is small enough to be housed in a room, consists of a smaller clockwork mechanism which drives several specialized dials depicting the movement of particular celestial bodies (Bedini & Maddison, 1966). It may be argued that both astronomical clocks and astraria were intended to be teaching aids, since they illustrate particular cosmic theories in a tangible manner. While these devices may have been used in this way, their main purpose was likely to indicate approaching religious festivals (Bedini & Maddison). Neither astraria or astronomical clocks can be considered as teaching machines, since there is no provision for input.

There is some evidence to suggest that knowledge of manually-driven mechanical planetaria was re-introduced in the West during the fourteenth century. North (1966) provides a copy of and a commentary on an anonymous work, the *Opus quorundam rotarum mirabilium* [work on certain marvelous wheels], which he believes was written either in the late thirteenth or early fourteenth century. It describes a geared device that was supposed to illustrate the relative orbits of the known planets and the sun about the earth by means of representations that were moved through gear arrays (North, 1966). Although the description of the device contains a substantial amount of technical detail, including information on the gear ratios, the language used in the original text is sufficiently vague to provide confusion about the possible appearance of the device. It seems likely, however, that the mechanism drove small spherical representations of the planets and the sun with a larger, parchment-covered sphere at the centre representing the earth. Apart from the earth, which was mounted onto a fixed shaft, the other planets and the sun were each connected to the gear array by means of wires, although North (1966) believes that dials could have been used instead. The device also included a variety of volvelle, probably a fixed scale arranged in a circular fashion outside the largest orbit, that enabled the user to determine the time of day. Despite the inclusion of technical details, the text does not indicate how the mechanism was to be driven. North (1966) suggests that since it would be possible to tell the time by means of the volvelle, it is likely that the device was driven by some form of clock mechanism. If this analysis is correct, then the device would be a simulation of the solar system in real time. It could be used as a teaching aid only, therefore.

North (1966) also states, "it is possible, but surely unlikely, that the device was driven manually, for merely educational purposes" (p. 362). It may be argued that since the text did not describe the motive power of the mechanism, it should be assumed to be hand-driven. In support of this contention, it should be recalled that astronomical clocks are noted above as being in existence in the thirteenth century, that is, at about the same time as the account of this planetary device; the previous section concerned with Islamic planetaria notes that a weight-driven planetarium may have been constructed early in the thirteenth century. Given the fact that knowledge of weight-driven mechanical planetaria and the knowledge of astronomical clocks was widespread by the time the work was written, it seems likely that had the planetarium described by North (1966) been intended to function as a real-time simulator, the text would have noted that point in some manner.

It seems likely, that this mechanical planetarium was a development of the established and accepted trend of employing teaching aids for instruction in astronomy. The ancient world had had a tradition of employing mechanical planetaria for instructional purposes, as we have seen in the previous chapter. Although a direct connection between the ancient planetaria and the device described by North cannot be demonstrated, it is possible that the re-discovery and the appreciation of ancient sources induced scholars to adopt, or to at least try, some of the pedagogical methods developed by the ancient Greeks and Romans.

It is possible that the planetarium described by North was used as a teaching machine. By turning a drive shaft by means of a crank or a wheel, users could observe not only the relative motions of the planets and the sun about the earth, but they could also observe, by means of the volvelle, that the actual movement of the planets in the solar system is related to time. It would also be possible to observe why certain astronomical events such as eclipses occur only at specific times and that these times can be predicted because the celestial bodies move in a regular and constant fashion.

There is no evidence to indicate whether or not the planetarium was constructed. North (1966) claims that the text may have been a theoretical work and that an actual example was never constructed. It seems likely, however, since teaching aids for astronomy were in use by this time, that the account of the fourteenth century planetarium represented, at the very least, an awareness of the possibility of using teaching machines for astronomy. Additional support for this view comes from the fact that by this time ancient sources such as Cicero and Quintilian were known and studied by some scholars and educators (Smalley, 1960). While no direct evidence exists to indicate that knowledge of mechanical planetaria was derived from re-discovered ancient sources, there are indications that other instructional devices and methods of pedagogy were.

Hornbooks

One of the major problems in teaching a number of students simultaneously is ensuring that each individual perceives the information being taught in roughly the same manner, so that what is being learned by each is what the instructor intends. It has been noted in Chapter II that some ancient educators, most notably Quintilian, encouraged their students to use wax-covered tablets for taking notes. Quintilian also points out that until a student learns how to write the alphabet and how to write on the wax surface, a tablet would not be of much use. One method of teaching the alphabet entails students playing with ivory letters. Quintilian believed that by having the letters loose the students would learn to recognize each letter independently of its order in the alphabet. In this manner, recognition of the letter itself would be learned, not by way of its position in the alphabet . While this method may have worked, there are some disadvantages to it. Disregarding the expense and the comparative rarity of ivory, since it would be a simple matter to construct the letters from inexpensive wood, loose letters can easily be lost and are susceptible to damage. Also, by allowing students to play with loose letters, it is possible that some of the letters would not be touched; the result would be that the student would not learn some of the alphabet. Whether these factors were considered by educators in the West beginning in the thirteenth century is not certain. What is certain, however, is that while some educators from this period acknowledged the pedagogical contributions of Quintilian, the methods that they employed to teach the alphabet varied considerably from what Quintilian advocated.

One of the earliest accounts of instruction in the alphabet is a transcript of a sermon by the Dominican friar Robert Holcot, probably written early in the fourteenth century (Orme, 1973). Holcot describes what he calls a *book* which consisted of large printed letters which were affixed to a board,

> You know that boys, when they are first being instructed, are not set to learn something subtle, but something simple and so they are taught first in a book with large written letters affixed to some wooden thing and afterwards, step-by-step in letters of a smaller book. (in Smalley, 1960, p. 332; translation by Buck).

It is not clear, from Holcot's description, whether the item he refers to is a large page that was tacked to a board displayed at the front of the class in the same manner as a modern poster or flip-chart, or whether the arrangement was a small page attached to a small board that was designed to be held in the hand of the student. In the first instance, Holcot's contrivance would represent a precursor to the blackboard, while the second possibility would indicate an early appearance of a teaching aid known as a hornbook. In either case, the intended use of the apparatus would be as a teaching aid. An English poem, believed to have been written about 1372 also describes a similar *book*. From this description it seems that what is being described is a hornbook (Orme, 1973).

Hornbooks were made of many materials, in many sizes and varieties, but all of them followed a basic design. The alphabet and sometimes the digits 0 through 9, as well as a brief prayer or quotation from the Bible would be attached to a holder designed to be held in the hand of a young student. In most instances, hornbooks consisted of a square or rectangular wooden board that had a small handle protruding from one edge. A piece of parchment or paper containing the material to be learned would be attached to one side of the holder either with tacks or glue. A thin covering of transparent horn was frequently attached as well to protect the sheet from damage (Tuer, 1896). It is likely that this type of hornbook was used as a reference for the student, and possibly as a guide to forming letters. The horn covering would allow a student to trace the letters or numerals using some sort of temporary medium such as tempera, that could be removed easily from the horn surface. In this manner, a hornbook would function as a teaching aid. Other types of hornbook exist to suggest that they were used for letter tracing.

There are surviving examples of horn books made of lead or silver that have the information engraved on their surface (Tuer, 1896). It is most likely that these examples were used in much the same manner as Quintilian's lettering practice board. Apart from their extreme weight, metal hornbooks were probably more expensive than their wooden and paper counterparts. It seems, however, that hornbooks rapidly became an important teaching aid in the West during the later years of the mediæval period. There are numerous woodcuts and engravings from this time depicting students using hornbooks (Tuer, 1896). At least one illustration implies that a hornbook is an essential instructional item if a novice student is to learn the requisite information to permit entry into higher halls of learning. Figure 17 (after a woodcut from the *Margarita Philosophica,* 1486, in Lacroix, 1877, p. 571) depicts an allegory of a student gaining entry to a *tower of knowledge* by means of learning the alphabet from a hornbook. This illustration indicates that the hornbook was considered in some circles not only to be an important teaching aid, but as a means of realizing individualized instruction, since the hornbook was presented to the student before he entered the tower of knowledge. It should be noted that primers, which are specialized books intended to instruct the rudiments of grammar, both of English and Latin, have existed since the thirteenth century (Orme, 1973). It may be contended that the additional information contained in primers, plus their ready availability would have resulted in a rapid disuse of hornbooks. The fact that this did not occur adds support to the contention that hornbooks were primarily intended to be teaching aids, rather than sources of new material like primers. Most primers were usually more expensive than most hornbooks, so economy may have been another factor resulting in the prevalence of the hornbook over the primer. The use of hornbooks continued well past the end of the mediæval period (Tuer, 1896). They were, however, not the only new teaching aids devised in the West during the later mediæval period.

Later use of the fingers

It is noted in a previous section concerned with finger reckoning, that the use of fingers as a teaching aid for arithmetic was likely not a continual tradition during the mediæval period. The fingers remain as very convenient objects to use as adjuncts to instruction, however. This realization may have influenced Ramon Llull (1232-1316) a Catalonian writer and philosopher, to employ a mnemonic system to assist individuals to learn his philosophy of the universe (Bonner, 1984). Llull's philosophic system, based upon sanctioned Christian tenets, consists of a number of complex combinations of letters of the alphabet, which signify discrete concepts of the philosophy. By arranging the letters in particular combinations, aspects of the *truth* would be demonstrated logically. To assist the user in learning the significance of the letters, Llull employs a mnemonic device using the hands that is similar to the memory aid known as the *method of loci.*

This method, which some maintain was devised by ancient Roman orators (Gage & Berliner, 1988) entails the pairing of discrete ideas or concepts to be remembered with

Figure 17. Allegory of learning containing a hornbook

familiar objects that are either visible or which are contained within a mental image of a familiar venue. If one wishes to remember a grocery list, for example, one can place a mental image of each required item on mental images of different pieces of furniture in, say, the bedroom of their dwelling. Bread might be placed on the bed, a carton of milk on the chest of drawers and carrots on the chair. By recalling the mental image of the bedroom when at the store, it is contended that the individual will also imagine the grocery items placed on each object in the room. In this manner, the grocery list will be recalled with a higher degree of accuracy than if the individual had tried to memorize the names of the items only. A simpler version of this method is to associate discrete ideas or information with specific appendages of the body. It may be that Llull devised his demonstrational philosophic system from this premise.

To assist individuals in remembering the letters and their significance, Llull employs a system where specific letters and their implicit meanings are associated with portions of the fingers on the left hand (Bonner, 1984). In this method, an individual has to memorize the significance of the letters and their position on the fingers. It is not necessary to memorize the combinations of the letters as well, since the association of each letter with a particular part of the fingers would probably provide a sufficient cue to enable the individual to recall the letters independently of a combination. In this case, the fingers would serve both as a teaching aid as well as an aid to memory. It is not revealed whether or not Llull's method was successful in helping individuals master the intricacies of his philosophical system.

A similar method of using fingers as teaching aids was devised in England by John Holte, an instructor at the grammar school of Magdalen College in Oxford during the late 1400s (Charlton, 1965). Holte devised a digital system both for learning and for remembering the basic rules of Latin grammar. While the knowledge of rules and their use is essential for the mastery of any language, one is not necessarily compelled to employ rote memorization. It should be recalled that the Roman orator and educator Quintilian disapproved of the use of rote work and instead favoured instructional methods that enable the learner to understand the concept or principle being taught (see Chapter II). Holte also seems to have disapproved of rote memorization. Instead, he employed a system that is similar in principle to Ramon Llull's.

Latin grammar contains five declensions and each declension also includes six cases. To use Latin properly, one must be able to recall the declensions as well as the appropriate cases. It is possible that by reducing the number of discrete concepts that a student has to memorize at one time, the material to be memorized will be learned in a more efficient manner and possibly at a faster rate than if the student attempts to memorize all of the required concepts at once. Holte designed a mnemonic that associates the Latin cases with the digits and the palm of a single hand. Although it is still necessary for the student to memorize the six cases of the second declension, for example, he/she does not have to remember that there are no more and no less than six cases, since cues are provided by the digits of the hand. Also, if the student uses a version of the method of loci when learning the cases, it is possible that the appearance of a particular digit will be sufficient to elicit the memory of the case associated with it. Figure 18 (after a woodcut from Holte's *Lac Puerorum*, 1479) illustrates Holte's system of case association for the second declension.

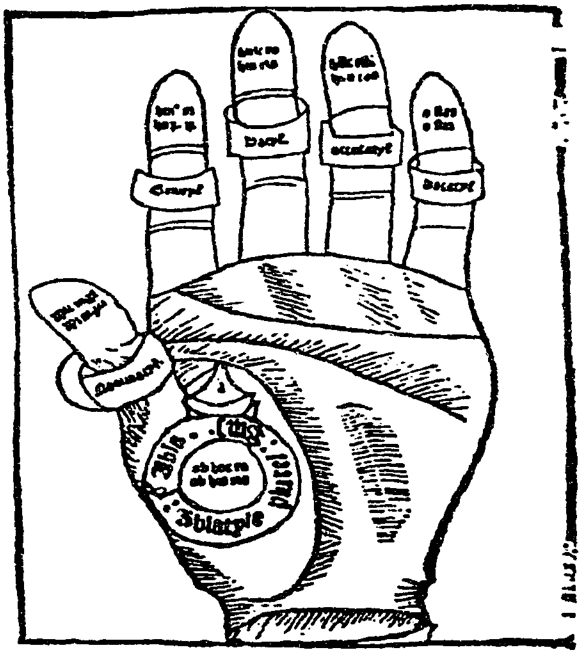


Figure 18. Hand depicting location of Latin cases

The drawing also includes the depiction of bands around each finger and the thumb. It may be that these bands are intended to be further cues to the learner, so that particular cases are associated with each finger. With extensive practice, it is likely that the student will learn the rules sufficiently to eliminate the need for the mnemonic. It is debatable whether or not Holte's method of instruction enables pupils to learn the grammatical rules of Latin in an easier fashion than by rote memorization. It is apparent that Llull, Holte and perhaps others, considered the fingers to be useful teaching aids.

Slates and blackboards

It is noted in Chapter II, that most writing by students was done on wax covered tablets. Although wax tablets can be reused a number of times by scraping the surface, this operation requires some time and considerable skill to be done efficiently and properly (Smith, 1958). As pointed out by Quintilian, students have to be taught how to use a stylus on the wax surface in order to write properly.

At some point by the fifteenth century A.D., it was discovered that a piece of flat quarried slate could be written on with a contrasting and softer material, and that the image left by the softer material (usually chalk or gypsum) could be removed easily by rubbing with a hand, cloth or similar material. The earliest known reference to slate used for this purpose is from a work of 1483, which notes that the ability to erase the surface quickly and easily is a major advantage of the slate over a wax tablet (Smith, 1958). The advent of the slate could not only facilitate the work of the students, but it could also be used as a teaching aid.

One of the most universal teaching aids found throughout educational institutions in the twentieth century is the blackboard or its variants, the chalkboard and the *whiteboard*. It is believed that blackboards were used initially in counting houses for calculations (Smith, 1958). In addition to providing a surface that is easily written upon and erased, blackboards enable others to observe what has been done on the surface. While the blackboard by itself does not function as an aid, it does assist the instructor in presenting material to a student or a class. This consideration is important to instructors if they wish to reduce the likelihood of students misconstruing oral instruction. Without visual cues, a student's concept of what is being described orally might well be different from what the instructor intends, or the instruction might simply be confusing to the student. Although books and teaching aids such as hornbooks do provide visual information and cues, they are usually limited in the extent to which they describe the concept. Several individuals in one class might not understand multiplication, for example. By illustrating each step of the operation on the blackboard, the instructor is able to explain what is occurring with greater clarity. While it is possible to produce books with similar attributes, such detail may not be necessary for most people. The printed illustrations, therefore, would be an additional and a largely unnecessary expense. A blackboard also enables an instructor to present information that is solely visual in nature. While there are other uses for the blackboard, it is clear that it can function as a teaching aid.

The idea of presenting visual information to an entire class simultaneously may not have originated with the blackboard. There is evidence to show that walls were used as rudimentary blackboards. Some of this evidence, dating from the late fifteenth century or the early sixteenth century, consists of alphabets painted on the whitewashed surface of a wall in a church vestry in England (Orme, 1973). Such an arrangement would not permit the easy erasure of information as on a blackboard. A wall would, nevertheless, enable an instructor to present visual information to an entire class simultaneously in the same manner as a blackboard.

Conclusions

It has been shown that the development and the deployment of both teaching aids and teaching machines in the mediæval period did not always follow a linear progression. It has also been shown that factors such as religious beliefs, curricula, economic considerations and available technology all affected the use of instructional devices. It is likely as well, that wars and plagues affected the development and the dissemination of instructional devices negatively. Throughout most of the mediæval period, the pedagogical merits of instructional devices seem largely to have been subordinate to considerations of other factors. Pedagogical considerations appear to have regained prominence in the West by the end of the fourteenth century, since instructional devices for astronomy, based upon Islamic examples, were by then generally considered to be acceptable. Most instructional devices from this period seem to have been adapted from objects designed for other purposes, such as armillary spheres and the blackboard. A small number of devices, such as the Islamic geomancy instructor and some mechanical planetaria, appear to have been designed primarily for instructional purposes.

Although the use of instructional devices was largely restricted in the East and the Islamic world by the end of the mediæval period, their use in the West was not only re-established, but new devices were also being developed. Some of the instructional devices mentioned in this chapter reflect an apparent awareness that there may be more than one way for individuals to learn. Evidence for this viewpoint includes: the use of mnemonic devices; the concern for significance rather than dependence on rote memorization; the use of manipulative materials rather than verbal or textual explanations; the introduction of models which are dynamic in time. Social considerations, however, had played the decisive rôle in the deployment and in the development of instructional devices. It would not be the last time that this occurred.

Chapter IV

Instructional devices from 1500 to 1900

Introduction

It was noted in the previous chapter that perceived pedagogical needs in particular situations and locales appear to have been the predominant factor that led to the introduction and use of some teaching aids and teaching machines during the mediæval period. Whether or not these devices continued to be used was determined largely by other factors such as social considerations. By the late sixteenth century, likely as the result of the Renaissance and consequent interest in education in general, it seems that there was also an increased interest in describing methods of pedagogy, the ideas or theories behind them as well as in explaining why it would be advantageous for teachers to adopt these methods. It will be shown that the gradual increase both in interest and in awareness of pedagogical theory and perceived needs led to a displacement of social considerations as the decisive factors in determining the use and the development of instructional devices. Although the primary concern is with teaching machines, it is evident that the development and the use of teaching aids during this period created a pedagogical basis and a theoretical foundation for the re-introduction of particular teaching machines as well as for the introduction of entirely new models. It is for this reason that teaching aids will be considered as well as teaching machines.

Re-introduction of devices and changes to those in use

Pedagogical theory of Erasmus

Desiderius Erasmus (1466-1536) while not primarily a pedagogue, did write works on pedagogical methods and the theories and ideas behind them. His theory about the way young students learn is based on the premise that the greatest learning occurs if the student can observe a given concept in a tangible way (Erasmus, 1985). It is likely that Erasmus developed his ideas about learning and pedagogy from Quintilian, since Erasmus makes frequent references to his works. The use of teaching aids is, therefore, an essential component of Erasmus' system of pedagogy. He advocates the use of illustrations and pictures to supplement lectures and explanations of objects and principles. Erasmus cautions that the teacher should select illustrative material in a careful manner, so as to ensure that it is, "especially agreeable, relevant, and attractive..." (Erasmus, 1985, p. 307). He also promotes the use of three-dimensional teaching aids to encourage recalcitrant students to learn particular lessons or concepts. He states that this idea comes from accounts written by teachers of antiquity. The idea probably originates with Quintilian. Erasmus, like Quintilian, also describes the fabrication of letters of the alphabet, from ivory, that are to be given to young children to play with so that they might learn the significance of each letter. A similar approach, that uses a different variety of teaching aid is not described by Quintilian, but is attributed to ancient origins by Erasmus, nevertheless. While it is possible that his claim is valid, a lack of evidence to support it suggests that this variation may have originated in the mediæval period.

Cookie Letters

Erasmus (1985) describes how some teachers bake sweet cookies in the shape of letters of the alphabet. Upon the correct identification of a particular letter, the student is rewarded with that letter, which is meant to be eaten. In this manner, similar to Quintilian's use of ivory letters, students learn the form of each letter independently of order. This method is thought to alleviate the problems of letter recognition encountered by students who are taught the alphabet by rote. Erasmus' conclusions about how students learn are practically identical with those of Quintilian. Erasmus (1985) notes, "At present, children are tormented by endless obscurities and difficulties caused by the fact that they are taught the names of the letters before they can identify their forms..." (p. 340). Like Quintilian, Erasmus maintains that the learning of complex operations can be facilitated by dividing them into discrete and simpler sub-tasks. The idea of analyzing the complexity of an operation and reducing it to a sequence of simpler skills or tasks is similar to the modern approach of *task analysis* as advocated by Robert Gagné (1965) and others. By learning the form and significance of each letter of the alphabet independently of order, the student is required to attend to one task only. Once the teacher has established that each letter is recognized by the students and that they are able to demonstrate that each letter represents a discrete concept, then the order of the alphabet can be taught. In this way, learning the order of the letters will not interfere with learning the significance of each letter. This approach emphasizes the importance of visual discrimination in learning.

Unlike ivory letters, which Quintilian considers to be effective teaching aids because of their tangible nature and their novelty, the cookie letters embody a learning theory based upon the concept of reward or reinforcement. Not only are cookie letters tangible and novel, but they are also likely to be considered desirable treats. The provision of such treats is likely to reinforce the behavior that led to their acquisition. The prospect of receiving a treat for appropriate behavior, providing the desired answer in this instance, may motivate students either to perform the desired behavior initially or it may motivate them to modify behavior considered undesirable. If this explanation of the pedagogical purpose of the cookie letters is an accurate representation of what was intended, then the theory of learning embodied in this method of pedagogy bears similarity to some of the behavioristic approaches developed in this century, such as the one devised by B.F. Skinner (1954). It may be contended that a cookie letter serves firstly as a discriminative stimulus and secondly, if the response elicited is correct, as a positive reinforcer.

Erasmus does not elaborate further upon the cookie letters, nor does he reveal whether or not the principle was applied to other subjects. His description of other contemporary methods of pedagogy suggests that the use of teaching aids was widespread in Europe by that time. An example is his account of an English method of teaching both the Latin and the Greek alphabets to young students.

Archery Targets

The method that Erasmus describes is one that a particular English father devised for his son. The father prepared a special archery target that had letters of the Greek alphabet affixed to it. His son, who enjoyed archery, practiced using the special target. Each time an arrow struck a particular letter, the son was required to identify it correctly. A degree of randomness is possible with this method. A correct identification of the letter resulted in positive reinforcement such as applause, a cherry or anything else that the child considered pleasurable (Erasmus, 1985). Some contemporary behaviorists make a distinction between types of reinforcers. *Primary reinforcers,* the cherry for example, satisfy or reduce basic needs such as hunger. It is not stated whether or not the child in this instance was purposely deprived of food before attending class, to intensify his hunger so that it might act as a motivator. It is likely that this was not done, at least intentionally, since Erasmus was against using any aversive methods to either initiate or facilitate learning (Erasmus, 1985). *Secondary reinforcers,* such as applause, act as reinforcers because they are associated with primary reinforcers through conditioning (Hergenhahn, 1988). It seems that a distinction was not made between primary and secondary reinforcers by Erasmus, yet he was aware that only certain objects and actions are effective as reinforcers, since he notes that the rewards given should be pleasurable. Erasmus also maintains that better results can be obtained if this method is applied to groups of two or three students who compete with one another for the reward (Erasmus, 1985). In this situation, an individual would receive reinforcement intermittently. The contention that intermittent reinforcement is superior to continuous reinforcement is shared by many contemporary behaviorists (Hergenhahn, 1988). The type of instruction using archery competition, as described by Erasmus, appears to concur with this behavioristic idea. Competition may also enhance individual motivation.

According to Erasmus, the use of archery as a teaching aid-based method of instruction is more efficient than employing lecturing and memorization. Erasmus (1985) notes that the son learned the alphabet in only a few days, while some students in schools did not learn the alphabet after three years of study. He attributes poor scholastic performance to the way most teachers treat their students. Most teachers employed aversive techniques such as beatings, threats and insults to motivate their students to learn as well as to discourage them from making incorrect responses. While Erasmus did not make the distinction between types of reinforcement, his awareness that pleasurable feedback to appropriate student responses (positive reinforcement) results in greater motivation to learn than when punishment is provided for inappropriate responses, indicates that he considered pedagogical method to be the decisive factor affecting learning. Although Erasmus' accounts are anecdotal and possibly exaggerated, they indicate, nevertheless, that some comparisons were being made between different methods of instruction and that his advocacy of instructional devices was based on a consideration of learning theory primarily.

While Erasmus promotes the use of teaching aids, he warns that they can hinder learning if they are deployed without due consideration. Erasmus (1985) contends that excessive use of aids, or using aids that are too complex for the students, will add to the difficulty of learning the main point or concept of the lesson. He claims that certain teaching aids and specific types of memory techniques, especially mnemonic devices, are not effective. Moreover, Erasmus (1985) states that such techniques and teaching aids are contrivances, "which seem to have been dreamt up only to serve personal gain or fame rather than for any useful purpose; in fact, their effect on the faculty of memory is quite harmful" (p. 340). Although Erasmus condemns certain teaching aids while promoting the use of others, he does not provide specific criteria for assessing the appropriateness of teaching aids. It seems that teaching aids were gaining widespread acceptance and use in spite of Erasmus' criticisms, since he implies that fame is associated with their invention and deployment.

Locke's Pedagogical Theory

John Locke (1632-1704) like Erasmus before him, decried the prevalent use of aversive physical punishment as a means of learner motivation and feedback (Locke, 1927, p. 33). Unlike Erasmus, however, Locke promotes the use of rewards and punishments in combination to encourage learning. Locke (1927) does not approve of the type of rewards (reinforcers) advocated by Erasmus namely, "Things that are pleasant to them [students] ..." (p. 32). Locke's explanation of this position is that if one provides such pleasant reinforcers to students each time they learn something, then it is likely that they will come to expect such reinforcement always. The ultimate result will be that the students will not do anything unless they are bribed.

While Locke (1927) contends that both rewards and punishment are excellent motivators for children, he states further that physical rewards and punishments succeed only in reinforcing undesirable behavior, "The Pains and Pleasures of the Body are, I think, of ill Consequence... they serve but to increase and strengthen those inclinations, which 'tis our Business to subdue and master" (p. 33). Locke prefers the use of secondary reinforcers such as esteem and disgrace as motivators for learning. Although Locke rejects the use of physical reinforcement and punishment, he encourages the use of teaching aids.

Dibstones

Locke (1927) claims that certain material can best be learned by extensive repetition and practice. Such practice will result in the formation of habits of action not dependent upon the recollection of the action. The activity of practice need not be dull or formalized, however. To teach the alphabet, for example, Locke (1927) advocates the fabrication of "Dice and Play-things, with the Letters on them to teach Children the *Alphabet* by playing" (p. 132). Locke's method is similar to Quintilian's use of ivory letters, but Locke goes further by suggesting ways in which learning the alphabet can be made an interesting game. He describes a contemporary who pasted drawings of the five vowels plus Y onto the faces of a die. The consonants were placed on the sides of three other dice. Players throw all four dice at once, and then identify the letters displayed and attempt to form a word from them . The game, called *dibstones,* is intended to aid in the instruction of the alphabet primarily, but Locke implies that it can also aid the teaching of spelling, provided that a meaningful word can be made from the visible letters. There is other evidence to show that the use of letter games was known of and advocated by others.

Sir Hugh Platt (in Tuer, 1896) describes a game he devised about 1653, that employs wooden blocks with letters of the alphabet inscribed on their surfaces. By rolling the blocks on a surface in the manner of rolling dice, different letters will be presented. Through identifying the letters after each roll, Platt contends that the players will learn each letter and will also receive extensive practice in identifying them. The similarity of this game with Locke's dibstones is great, and it may be that Platt is the contemporary referred to by Locke. It should be noted that for either game to be effective, at least one of the players must know the alphabet, otherwise particular letters might either be identified incorrectly or not be identified at all.

Handwriting aid

Locke's pedagogical theory facilitated the re-introduction of another teaching aid devised by Quintilian. Locke, like Quintilian, was concerned with the difficulties of learning how to write. Both realized that in order to write, an individual must know what symbols to write as well as being able to control movement in the hand, wrist and arm. Quintilian's practice board (see Chapter III) enabled students to trace each letter of the alphabet with a stylus, thus providing practice in the correct movements of the hand, wrist and arm. Locke's conclusions about learning resulted in his invention of a similar teaching aid. Like Quintilian, Locke had engravings of the letters produced. The engravings were made on a metal printing plate, however, and copies were printed in red ink upon paper. After receiving a copy, the student traces each letter with a pen, using black ink (Locke, 1927). The course of the black ink, as compared to the red, indicates the accuracy of the student's writing. Locke reports that this corrective feedback assists students in developing proper writing skills. Locke (1927) also advises that the letters on the printing plate should be made "a pretty deal bigger..." than the usual appearance of writing (p. 136). His explanation is that it will be easier for students to trace larger letters and that the size of an individual's writing becomes progressively smaller over time.

Taylor's penmanship device

The idea of simplifying the process of learning how to write occurred to at least one other individual during this period. In 1877, John D. Taylor of the United States, patented a device designed to hold a hand in the correct position when learning to write (United States Patent No. 188,984, March 27, 1877). Like Quintilian and Locke, Taylor contends that learning to write correctly involves coördinating several skills at once.

Taylor's device consists of a shaped wooden board with a protruding wooden stabilizer bar. Through a system of elastic bands and finger loops, the apparatus holds the hand in the correct position for writing. Figure 19 (after United States Patent No. 188,984, March 27, 1877) shows the application of Taylor's penmanship teaching aid.

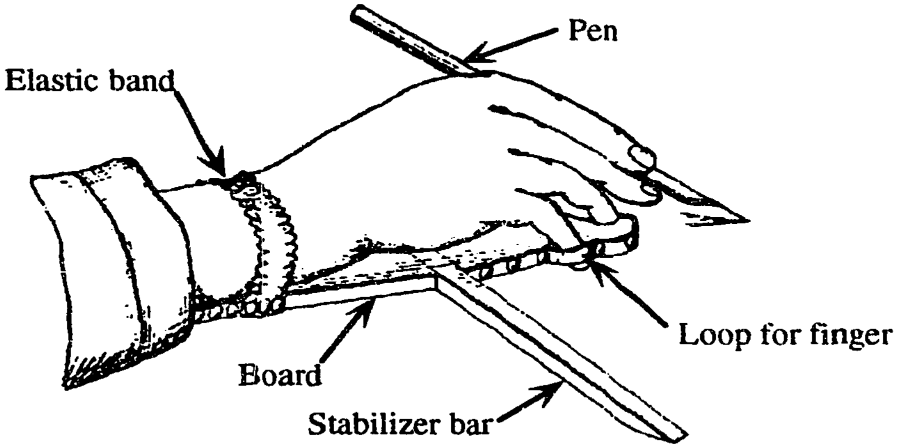


Figure 19. Taylor's penmanship teaching aid

In use, the device is intended to hold the hand and fingers in the correct position for writing, without much attention being given by the learner. In this way, the learner can concentrate on the task of forming the letters correctly, thus simplifying the process of learning how to write. It is not known if Taylor's device was marketed or used extensively by teachers.

Toys and battledores

It is evident, from the section concerned with dibstones, that Locke's advocacy of teaching aids extends beyond formalized educational environments such as classrooms, since he contends that most items considered play-things are of educational merit. Some toys, such as dibstones, are useful teaching aids because they provide children with repetitive practice, while simple objects of curiosity such as keys or unusually-shaped stones tend to increase a child's curiosity and interest. Locke (1927) contends that commercially-produced items are appropriate teaching aids if simpler versions cannot be made by the children themselves. Tops and battledores are among such commercial items Locke considers appropriate.

Battledores, which were common by the mid 1600s, appear to be derived from hornbooks (Tuer, 1896; see also Chapter III). Many hornbooks resemble paddles, so it is likely that some students used hornbooks in this way as well as for their intended purpose. If a hornbook is used to strike a ball or a shuttlecock, it is likely that the horn and/or the underlying paper or parchment will be damaged. Tuer (1896) suggests that a logical solution to this problem is the combination of the hornbook with a game paddle. The resulting hybrid is called a *battledore*.

Most battledores are made from wooden gaming paddles. The alphabet and sometimes other information is painted onto one or both faces. Instead of a horn covering, layers of varnish are applied for protection (Tuer, 1896). Figure 20 (after illustrations of battledores in Tuer, 1896) depicts a simple battledore.

Battledores can be used for two disparate purposes, as teaching aids, and as necessary tools for particular games. By redesigning the hornbook so that it better resists damage and combining the improvement with existing game paddles, a teaching aid is produced

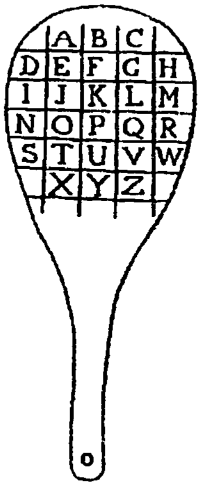


Figure 20. A typical battledore

that is robust and which is not limited to one purpose. Once a child learns all the information on a battledore, it is still useful as a game paddle. This type of battledore represents one of the first recorded instances where a teaching aid was improved by combining it with a common, non-instructional item. This combination also marks the beginning of the manufacture of toys that may also be considered instructional devices.

Battledores are probably more effective than hornbooks pedagogically. Hornbooks are useful teaching aids when they are looked at, but their construction limits their use to times intended for study. Information on battledores is visible to the user not only during times of study, but also when it is played with. In this way, it is likely for a child to be exposed to information for a greater frequency with a battledore than with a hornbook. It should be noted that the while common use of hornbooks in England and most European countries ceased by the beginning of the nineteenth century, hornbooks continued to be used in parts of North America and Africa well into the twentieth century (Tuer, 1896; Anderson, 1962).

Battledore books

By the mid 1700s, the term *battledore* was applied to a teaching aid markedly different from earlier paddle-type battledores, but which performed the same pedagogical function. Instead of printing the material to be learned on a paddle, the information was printed on card stock that was either shaped like a battledore, or which was folded like a leaflet or a triptych. This teaching aid, which can be used like a book or hornbook, is referred to variously as a battledore or *battledore book* (Tuer, 1896; Anderson, 1962). It seems that paddle-type battledores were modified in this fashion because of the factors of cost and productivity. While most of the work on paddle-type battledores was done by hand, the production of battledore books could be done by machine. Not only could production be increased, but the cost of each item could be kept comparatively low. Although battledore books are not suitable for games as well as for study, their low cost makes them more saleable and better suited to replacement than the more expensive paddle-type. The printer Benjamin Collins (cited in Tuer, 1896, p. 229) notes that he sold more than 100,000 battledore books between 1770 and 1780.

It is also possible that battledore books appealed to a greater market than did battledores. Children who either were not permitted to or disposed to play games at school would probably not have had paddle-type battledores. A battledore book, however, is suitable for most students. Battledore books are also more appropriate for adults, who are less likely to play childrens' games. In addition, there are examples of battledore books that appear to have been designed solely for adult learners (Tuer, 1896). Another advantage of battledore books is their smaller size. Apart from being easier to carry than battledores, battledore books can be carried in a discrete manner if desired. It seems that most individuals were used to the idea of using some sort of teaching aid for learning rudimentary material by the time battledore books were devised. It is likely, therefore, that it was no longer necessary to combine teaching aids with utilitarian devices to encourage both the sale and use of commercially-constructed teaching aids. The mercantile potential of teaching aids, however, meant that combination toys and teaching aids would not disappear. This aspect of instructional devices will be examined further in subsequent chapters.

Instructional cards

Instructional cards, like battledores and battledore books, are teaching aids that were likely developed from the hornbook. Jones (1980) states that cards containing printed information were first used for instructional purposes in Germany, beginning in the early sixteenth century. The cards, patterned after playing cards, contain information about philosophy and were probably used as teaching aids. While it is likely that this type of card was intended for use by adult students or by older children, Jones (1980) states that cards containing information about the alphabet, spelling, arithmetic, heraldry and geography were available by the seventeenth century. These types of cards would be suitable for use with young children. It is likely, given extant examples, that instructional cards were produced commercially and that the intended market for them was outside formalized schooling. It is also probable, therefore, that instructional cards were a viable commercial enterprise throughout this period.

One variety of instructional card called variously *charades* or *enigmas* was intended to be used by two people. One person takes a card and reads the question on it to the other person. That person answers if possible. Each player takes turns reading questions (Jones, 1980). This type of card appears to be a precursor to modern *flashcards* or to games such as *trivial pursuit* that may also be considered teaching aids. While it is likely that instructional cards were used primarily in informal settings, there is some evidence to indicate that such cards were being used as teaching aids in some schools as early as the eighteenth century.

Manson's instructional cards

David Manson (1726-92) an Irish educator influenced by Locke, also believed that learning could occur during play. Besides advocating the use of existing teaching aids and instructional toys, Manson designed a set of instructional cards that contain simple lessons in reading, spelling and arithmetic. It is intended that students play with the cards in an informal setting, thereby learning the lessons that they contain in a natural fashion (Stewart & McCann, 1967). While Manson considered this teaching aid a success, there is little evidence to suggest that his cards gained widespread acceptance and use by his contemporaries.

Wilderspin's Cards

Samuel Wilderspin (1791-1866) was an English educator who operated a school for young children. Wilderspin's approach, called the *infant system*, was derived ultimately from the pedagogical theories of John Locke (McCann & Young, 1982). The use of teaching aids is an essential component of both theories.

The existence and use of instructional cards has been mentioned in previous sections. Wilderspin adopted the use of instructional cards in general, but the way in which he modified them made them hindrances rather than aids to learning. A typical card might show the letter A and a depiction of an apple. Wilderspin's cards did not always depict an object that was readily recognizable or which was easily associated with the letter. An example is the card showing the letter X and a drawing of a man. The drawing was supposed to represent the ancient Greek soldier and historian Xenophon (McCann & Young, 1982). For a student to make any sense from the card, the depiction would have to be recognizable as Xenophon, not some other ancient Greek or a man in general. It is unlikely that most students would recognize Xenophon unless time had been spent showing them that illustration and associating it with his name. Such an elaborate procedure would not be required for familiar objects, likely encountered by students outside of school. Different types of instructional cards continued to be devised throughout this period, however.

Thompsons' instructional cards

Towards the end of the nineteenth century, many new designs of instructional cards were introduced which were intended to improve the efficacy of instruction in schools. Examples include the instructional cards devised and patented in 1896, by the Americans John and Thomas Thompson (United States Patent No. 569,846, October 20, 1896). While their cards are similar in principle to previous efforts, the Thompsons made some changes. Instead of a single card for each question or for each discrete item of information, each card was printed with several squares, each of which contains either one item of information or a question. The Thompsons' cards also came with separate printed squares that were intended to be placed on top of the corresponding square on the card. It is believed that by using this type of teaching aid, the child not only learns the symbol and the quantity or object that it represents, but also that there is usually more than one symbol to represent the object or quantity. Figure 21 (after United States Patent No. 569,846, October 20, 1896) depicts a portion of the main card of the Thompsons' instructional card system. The separate cards, intended to be placed on top of the main card, are not shown.

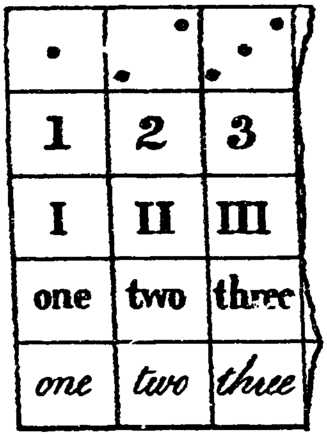


Figure 21. Portion of the Thompsons' instructional card

Other versions of the Thompson card system include ones for the names of particular animals as well as cards for learning the names of colours. While the Thompsons state that the cards may be used by a child on its own, they also state that the cards may be used by teachers as teaching aids. A possible problem with using the Thompsons' cards as a teaching aid in a large class would be enabling all the students to see the card at once, since no provision is made for hanging the main card or for attaching the individual cards to it. This problem was overcome by charts that were designed expressly to be classroom teaching aids.

Charts and maps

It is likely that charts and maps designed specifically as classroom teaching aids were developed at about the same time as instructional cards. As in earlier times, it was widely believed that visual demonstrations of a concept would facilitate its understanding. This was the theoretical premise of Louis Johnson of Spencer, Missouri. In 1888, Johnson designed a series of charts as teaching aids for illustrating the concepts of fractions. Figure 22 (after United States Patent No. 383,300, May 22, 1888) shows one of Johnson's charts.

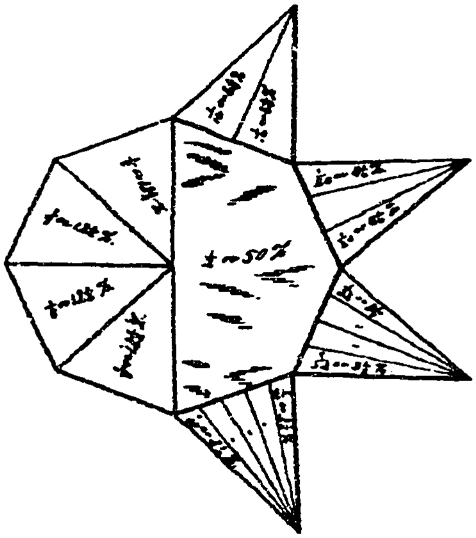


Figure 22. Johnson's teaching aid for fractions

Explaining the purpose of his charts, Johnson states, "It will be apparent that this ocular method of demonstrating the relationship between fractions and percentage will leave a durable impression on the youthful mind and affords an educational toy or factor of intrinsic value" (United States Patent No. 383,300, May 22, 1888). From his explanation, it is clear that Johnson concurred with the idea that abstract concepts are best taught by illustrating them in a tangible manner. Johnson does not support the claims he makes and he does not elaborate on how his charts could be used as educational toys or how they can be considered to possess an intrinsic value. Johnson at least tries to justify his charts from a pedagogical basis rather than from bases of cost or time-saving.

Word building frames

Another offshoot of the hornbook are the paddle-shaped teaching aids that can be used either by individual students, or by an entire class. Usually made of wood, most word building frames consist of a base resembling a hornbook. A series of thin, shaped wooden strips are nailed across the base, so that they are aligned parallel to each other. The strips are shaped so that lettered cards can be slid in between adjacent strips. In this way, either individual letters or entire words can be displayed. The overall size of most word building frames is large enough so that there is sufficient room to compose most common words. Figure 23 (after illustration in Tuer, 1896, p. 221) depicts the appearance of a typical word building frame.

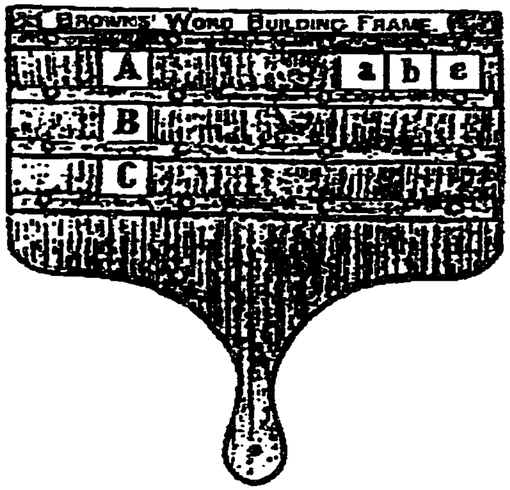


Figure 23. A typical word building frame

A teacher may use a word building frame to illustrate particular letters or the correct spelling of a word. To be effective and efficient, an ample supply of lettered cards are required as well as a means of storage that facilitates easy access to them. Word building frames may also be used by individual students learning to spell. Writing words on a slate or paper requires attending to two skills at once, writing and spelling. When an error is made on a world building frame, however, erasure is not required. By using a word building frame, only one skill requires attention, spelling. In this manner, it is possible for a student to learn how to spell particular words faster than by writing them. This rationale may have been a major reason why such teaching aids became common and why particular pedagogues advocated their use.

Word building frames fell into disuse in schools when blackboards and slates became common, since it is much easier and faster to write letters and words on a blackboard than it is to compose them on a word building frame. Some commercial concerns continued to market variations of the word building frame as late as the 1880s. These devices, known as *spelling sticks*, were claimed to be effective for teaching spelling to primary grades, since one letter at a time could be revealed (Anderson, 1962). While this process was being carried out, the teacher could face the students, something which cannot be done with any facility when writing on a blackboard. In spite of the claimed merits of spelling sticks, the blackboard prevailed as the main teaching aid in most classrooms. There is little evidence to show that spelling sticks or other types of word building frame were used widely at this time. Commercial production of word building frames, intended for private use and for domestic instructional games, continued throughout this period, which suggests that there was a market for them (Jones, 1980).

Loverin's historical centograph

The use of teaching aids during this period was not restricted to the subjects of mathematics and spelling. In 1878, Nelson Loverin of Montréal, Québec, received an American patent for a device to aid the teaching of history (United States Patent No. 198,749, January 1, 1878). The device, called *Loverin's historical centograph,* consists of a wooden frame divided by 100 small square compartments arranged in groups of nine which, in turn, are arranged in quadrants. The frame also supports a small blackboard on the top as well as a drawer underneath to hold a variety of symbol pieces. Figure 24 (after United States Patent No. 198,749, January 1, 1878) shows the appearance of Loverin's apparatus.

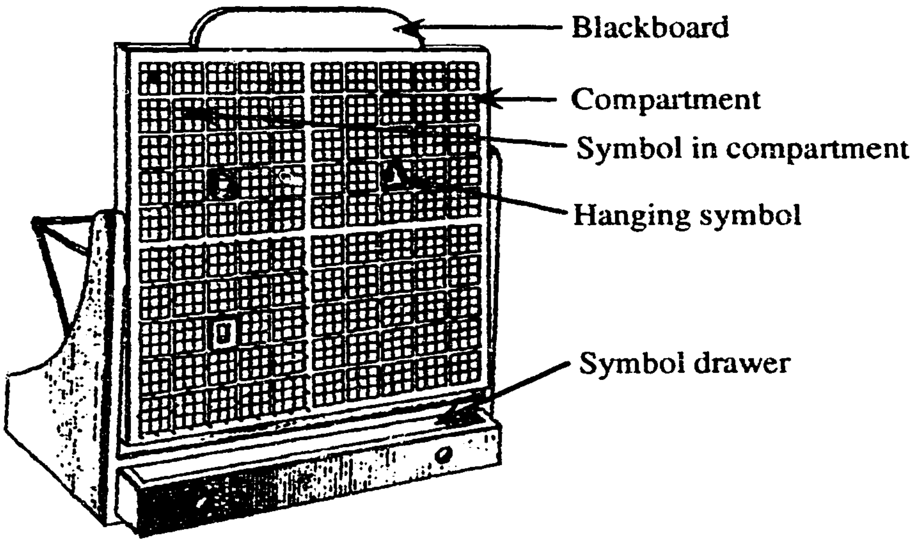


Figure 24. Loverin's historical centograph

The purpose of the device is to show the relationship of major historical events during a period of one hundred years. The time span may be written on the small blackboard. Each compartment represents one year. Small symbol pieces, designed to fit within the compartments, represent battles or other significant events. Larger symbol pieces are intended to be attached to hooks located above each group of nine compartments. These symbols represent features of a decade. By means of this apparatus, the student is supposed to develop a concept of how historical events are related. Loverin states that the centograph, "will serve as a powerful adjunct to the study of history, in familiarizing the student with time, a portion of which it always represents, holding historical events to view in chronological order..." (United States Patent No. 198,749, January 1, 1878). Loverin notes that the centograph may also be used as an adjunct in the instruction of statistics.

Although Loverin's device may show the chronological development of history in a visible manner, considerable time is required to set the apparatus up. There is one teaching aid that has now become a necessary tool, which can present a variety of information with a minimum of specialized equipment and without requiring much time for set up. That device is the blackboard.

Blackboard development

There is evidence to show that the blackboard was gaining widespread popularity by the beginning of the nineteenth century. Robert Owen (1771-1858) who operated schools in both Scotland and the United States, reportedly used blackboards as teaching aids (Stewart & McCann, 1967). While it is likely that early examples were fabricated from sheets of slate (see Chapter III) blackboards made of painted or stained wood are known from as early as 1809 (Anderson, 1962). The blackboard appears to be one of the first examples of an apparatus designed as a teaching aid and which has come to be considered a necessary tool. Anderson (1962) claims that, in the United States at least, the blackboard was considered essential for teachers at all levels by the 1840s.

Competitors of the blackboard

Arithmetical types

While it may seem that the transition from word building frames to blackboards was both logical and direct, there are examples of teaching aids that were designed to compete with the blackboard. Most teaching aids of this type are mechanical and can display a limited number of questions or information. There appear to be two main varieties. The first is characterized by a frame containing a series of parallel rods arranged horizontally. Each rods passes through the centre of a number of wooden blocks or slats which contain printed or painted letters, numbers or operands. The blocks or slats are designed to be rotated so that they reveal desired information or questions. The second variety presents information on some flexible material such as painted canvas, that is arranged in a continuous loop and which is supported on moveable rollers. Wooden or metal templates are used to obscure all but a specific portion of the information at one time.

An example of the first variety of presentation teaching aids intended to compete with blackboards, is the apparatus designed in 1877, by Charles E. Martin of Chicago, Illinois. Figure 25 (after United States Patent No. 196,532, October 30, 1877) depicts two versions of Martin's moveable block-type teaching aid, one with letters on the blocks, the other with numerals.

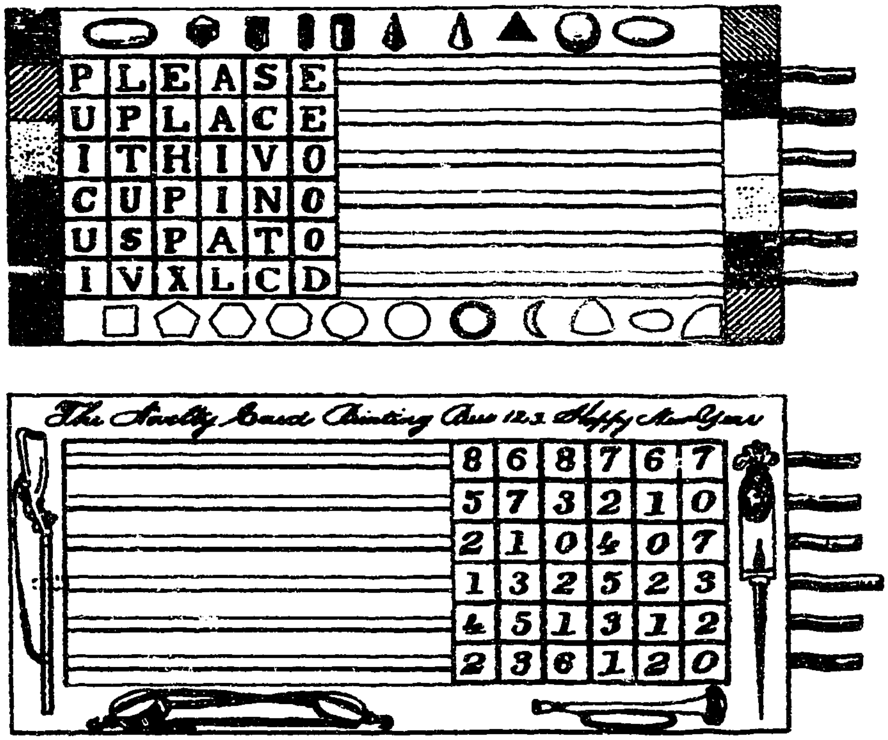


Figure 25. Martin's moveable blocks teaching aids

Similar examples include teaching aids referred to generally as *arithmetical frames*. These contrivances consist of a frame containing several rods that each support three slats arranged in the form of a triangle or a prism. The slats are designed either to hold printed cards, or the information is painted on the surfaces of the slats directly. Elaborate models also possess a system of sliders that are used to obscure portions of the slats or prisms. Figure 26 (after United States Patent No. 846,484, December 31, 1905) shows an elaborate version of an arithmetical frame teaching aid, designed by Andrew Leitch of Great Britain in 1905.

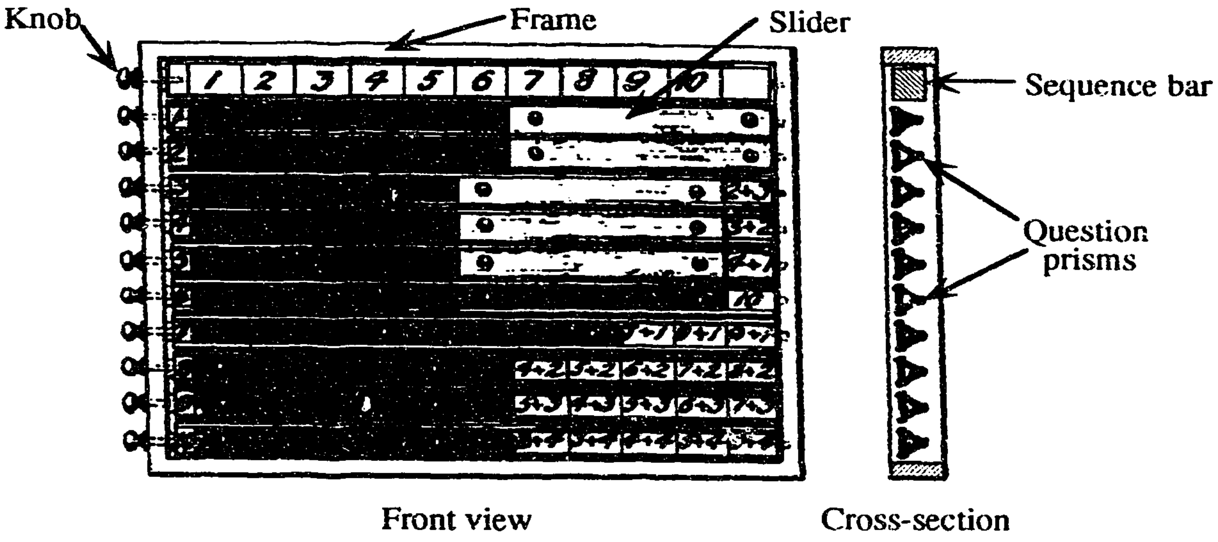


Figure 26. Leitch's arithmetical frame teaching aid

Literature describing a simpler arithmetical frame marketed by the American School Apparatus Company during the 1860s, lists two possible advantages of using arithmetical frames rather than blackboards (in Anderson, 1962). First, it is contended that the apparatus is far superior, pedagogically, to lessons and to examples in textbooks. The sales documentation states,

> the usual school arithmetics [textbooks and primers] contain examples sufficient to *illustrate* the rules, but far too few for *proper drill*, or practice. The *science* is taught, but pupils do not like to review the old pages... hence pupils fail to acquire, at school, the *practical art* of combining numbers rapidly. (in Anderson, 1962, p. 22)

It is assumed that drill and practice exercises facilitate learning, but no evidence is cited in support.

Second, arithmetical frames are supposed to save school boards and teachers both time and expendable supplies such as crayons and chalk. The sales information states,

> It will soon save its cost in the *time* of the teacher; it will save its cost in *crayons;* it will soon save its cost in books. Hence it is presented to school officers as the most *useful* and the most *economical,* and the most truly labor-saving piece of school apparatus ever invented. (in Anderson, 1962, p. 22)

The inability of this apparatus to perform to such standards, as well as the initial cost, probably contributed to the disuse and abandonment of this and other such teaching aids by the early years of the twentieth century.

An example of the second variety of teaching aid designed to compete with the blackboard, is the device patented in 1874, by Samuel Love of Jamestown, New York. The apparatus consists of a frame that supports two rollers arranged vertically. These rollers support a continuous belt of canvas or similar pliable material. One roller is also equipped with a tensioning mechanism to hold the belt in position and to provide sufficient friction to move the belt with the rollers. Numbers are printed on the material in such a way that only specific numbers will be visible through specially-designed wooden templates. A set of templates enable the apparatus to provide examples of the four basic arithmetical functions. The rear of the device is intended to store templates that are not in use. Figure 27 (after United States Patent No. 149,235, March 31, 1874) shows the front and top views of Love's device.

A simpler version of this type of teaching aid, is the device patented by Samuel Halleck of Oriskany, New York. Unlike Love's teaching aid, Halleck's is designed to be attached to a wall to aid visibility. Instead of using templates to obscure undesired information, Halleck's device employs a moveable curtain which is held in position by a counterweight mechanism. The apparatus is also designed so that the information belts can be changed. The belts are designed so that the numbers that they contain may be used to teach many different arithmetical operations. The extreme left-hand portion of the belt contains a sequence of letters which are visible when they are aligned with a hole in the curtain. The letters are used in conjunction with an answer key. The main purpose of the device is to save the teacher the time required to write exercises on a blackboard. Halleck writes, "A further advantage is that the figures will be correctly formed, and the scholar will be taught in that respect at the same time" (United States Patent No. 215,916, May 27, 1879). Figure 28 (after United States Patent No. 215,916, May 27, 1879), shows Halleck's version of an arithmetical frame teaching aid.

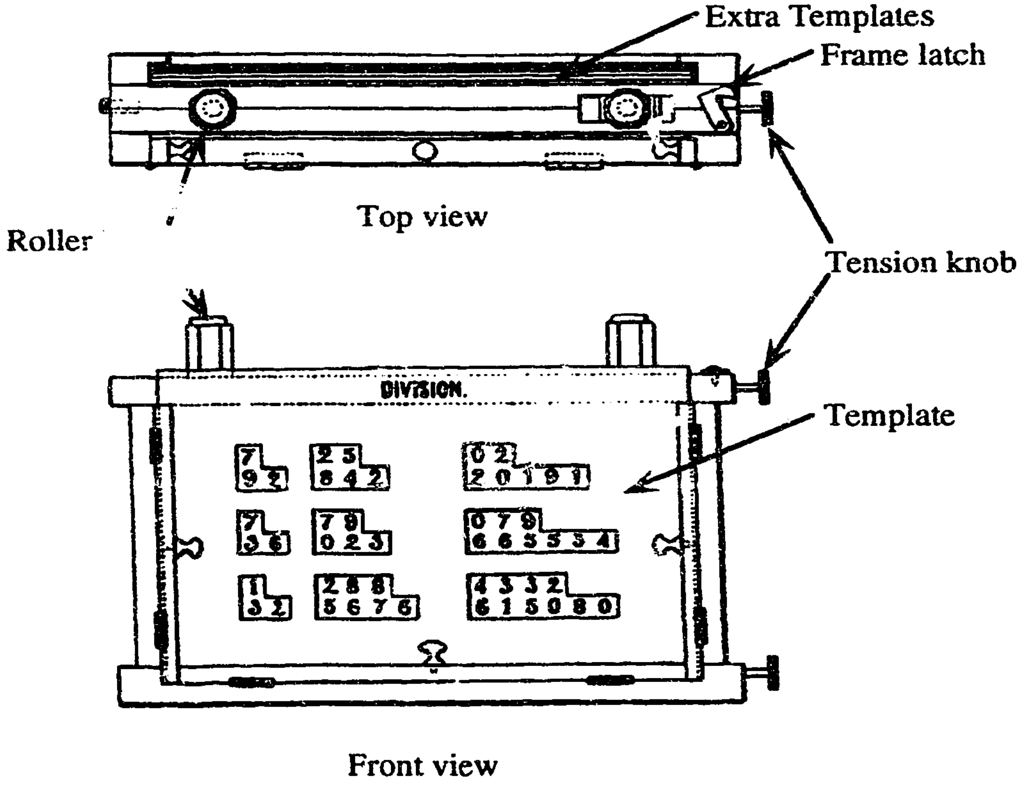


Figure 27. Love's teaching aid for arithmetic

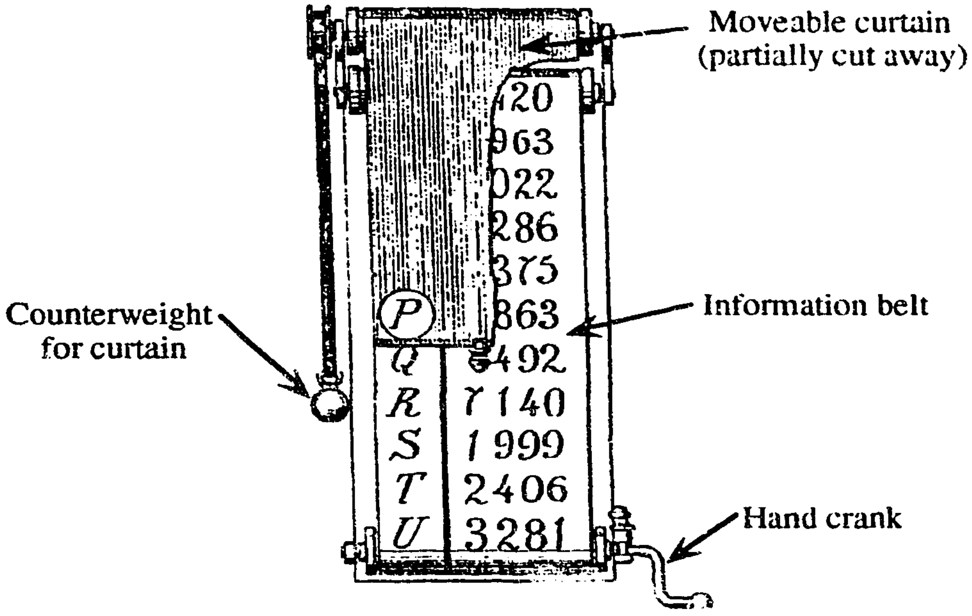


Figure 28. Halleck's arithmetical [illegible] teaching aid

Kavanaugh's teaching aid

Some teaching aids for arithmetic attempted to compete with the blackboard by incorporating features and actions that most blackboards do not have. One such device was invented by Richard Kavanaugh of Chaplin, Kentucky (United States Patent No. 196,583, October 30, 1877). Instead of using moveable blocks, belts or beads, Kavanaugh's apparatus uses pointers and spring-loaded holders to demonstrate principles of arithmetic. Figure 29 (after United States Patent No. 196,583, October 30, 1877) shows the appearance of Kavanaugh's teaching aid.

The interior of the device contains an elaborate mechanism that connects the index hand to the various card/object holders. In use, cards printed with sums or other arithmetic exercises are placed in the machine, so that the information is visible through the two semi-circular openings in the face. Objects or cards with pictures or drawings of objects are then placed in the holders. The mechanism is then set so that the card/object holders will either be exposed or obscured as the machine is operated. Pushing the unit knob causes the index hand to move clockwise by one increment. Depending upon how the mechanism is set, card/object holders will either remain stationary or change position. The holders along the top are intended to move up so that their contents become visible, while the holders along the bottom are intended to move in towards the centre of the machine, thus obscuring their contents. In this manner, addition and subtraction are simultaneously demonstrated in an enactive way. According to Kavanaugh, multiplication and division may be demonstrated as well, "as they are merely a shorter method of addition or subtraction" (United States Patent No. 196,583, October 30, 1877). Fractional numbers can be demonstrated with the aid of the beads located near the top of the device. It is contended that this apparatus embodies the principles of *object-teaching*. Kavanaugh states that his apparatus, "forms really an application of the principle of object-teaching to arithmetic, and facilitates the labors of the teacher, while impressing the different arithmetical operations in a perfectly lucid and clear manner on the mind of the child" (United States Patent No. 196,583, October 30, 1877).

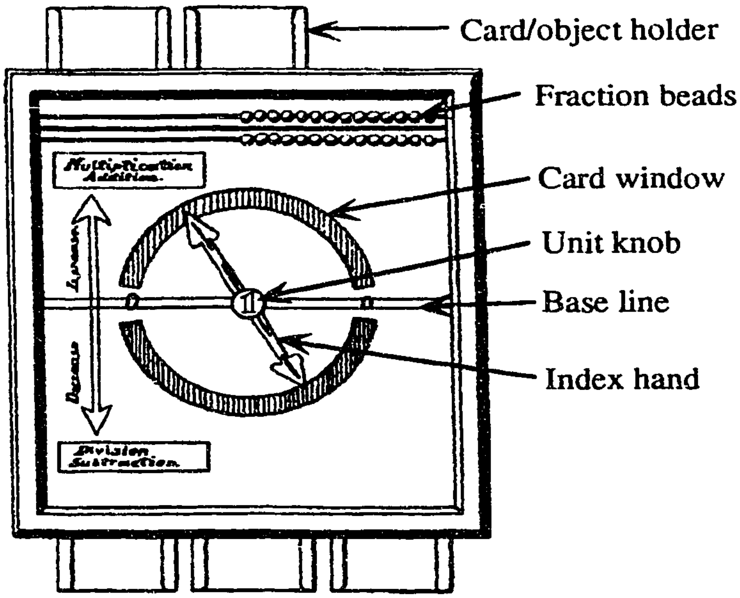


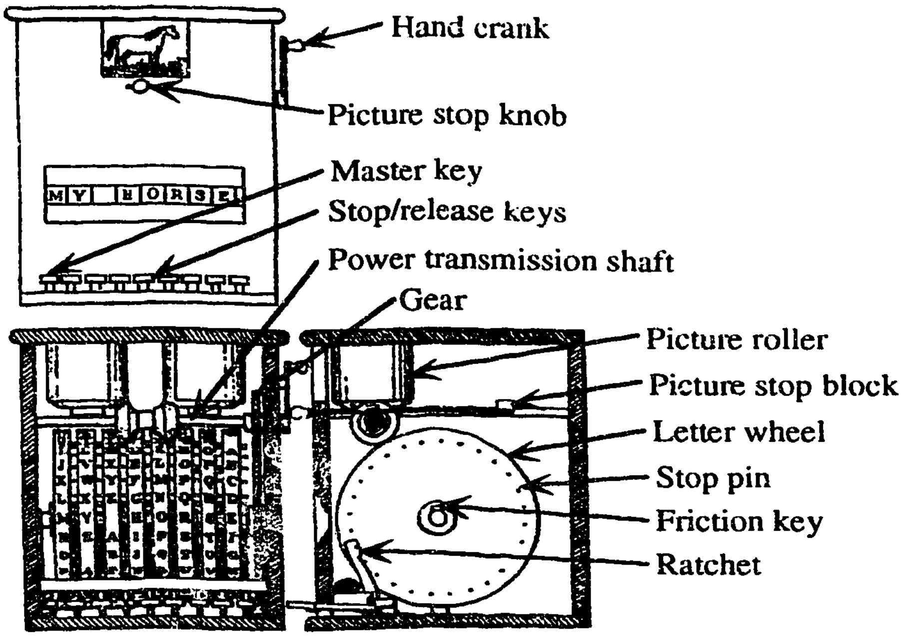
Figure 29. Kavanaugh's mechanical teaching aid for arithmetic

While Kavanaugh's device would probably attract more attention than a blackboard, its complex mechanism suggests that maintenance and repair could be a problem for the teacher. A teacher would also have to either set or reset the machine each time it is required. Although the principle of object-teaching continues to be followed by some educators, Kavanaugh's device is no longer used. There is also no indication that the apparatus was ever put into production.

Arithmetical frame-type teaching aids did not endure. Although they may add novelty to a lesson and save some time in creating exercises, they are limited to the numbers or information that they contain. Time is still required both to set the apparatus as well as to explain the assignment to the class. A blackboard is also required for additional exercises not available on the apparatus and for any operations that such teaching aids cannot do. Similar teaching aids were also devised for teaching spelling.

Mechanical teaching aids for spelling

Like arithmetical frame-type teaching aids, most teaching aids for spelling were intended to capture the attention of the pupil and to save the teacher time drawing on a blackboard (Anderson, 1962). Although there were simple designs, similar in appearance to arithmetical frames, most examples were complex mechanical affairs. One of the earliest is a mechanism patented in 1866, by Halcyon Skinner of Yonkers, New York. This apparatus consists of a wooden case housing a system of wheels, rollers and gears. Two rollers, located near the top of the case, hold a pliable belt containing drawings of objects. A series of eight wheels, located below, contain the letters of the alphabet as well as a blank space. A hand crank enables the user to move both the rollers and the wheels through a system of shafts, friction rollers and gears. A number of keys near the bottom of the case permit each lettered wheel to be stopped in a particular position. Figure 30 (after United States Patent Number 52,758, February 20, 1866) shows the general appearance of Halcyon Skinner's teaching aid. The front as well as a front cross-sectional and side cross-sectional views are shown.



Front cross-section Side cross-section

Figure 30. H. Skinner's teaching aid for spelling

The operation of the machine is fairly complex. To set the picture, one turns the hand crank in either direction until the desired picture appears in the window. The picture stop knob must be pulled out to stop the picture rollers from rotating. This action engages the picture stop block against the picture rollers. To set the caption, one must turn the hand crank in a counter-clockwise direction. Through a system of gears, the motion of the power transmission shaft causes all of the letter wheels to turn in a clockwise direction, provided that none of the stop/release keys are depressed. The picture rollers do not turn, however, because they are held in place by the picture stop block. When a desired letter of the first letter wheel appears in the window, the stop/release key beneath that wheel is depressed. This action causes a ratchet to engage a stop pin located in the side of the wheel. A small piece of flexible material such as rubber, called a friction key, enables the shaft supporting the letter wheel to continue rotating, even though one or more letter wheels are held in place by their respective ratchets. When all the wheels are positioned as desired, the apparatus displays the caption composed for the particular picture shown. In this manner, the device may be used as a teaching aid both for spelling and for teaching the names of particular objects. Resetting the device is facilitated by a master key located on the extreme left-hand side of the keyboard. When the master key is depressed and the hand crank turned in a clockwise direction, all of the ratchets are released and the letter wheels are free to turn once again. Pushing in the picture stop knob permits the picture rollers to rotate as well. The apparatus may then be reset to display a new picture and a new caption. It is likely that the apparatus did not function well, given the reliance on friction keys and rollers which are subject to rapid wear and decay.

At first glance, it might seem that Skinner's device is intended to be used as a teaching machine. Benjamin (1988) indicates that the vague description of it in the patent literature might lead one to this conclusion. While Skinner's device is not a teaching machine by definition, since there is no instructional feedback, there is evidence to establish that it was designed to be a teaching aid only. A similar device, *Jeffers' Panoramic Apparatus,* is described in an American school supply catalogue of 1879 (in Anderson, 1962). From the description, it is clear that such devices were intended to be used primarily by a teacher as a classroom teaching aid, "It can be quickly changed and adjusted... by the teacher, or even by the youngest pupil in school. The type is so large and plain that the words can be easily read across a room twenty-five feet in width" (in Anderson, 1962, p. 44). While there are at least two different examples of this type of teaching aid known, neither seems to have gained widespread use.

Given the versatility of the blackboard and its facility in presenting written information to a class, both by students as well as by the teacher, the claimed advantages of frame-type teaching aids were most likely outweighed by the advantages of the blackboard. Although the development and the use of teaching aids was becoming widespread during this period, there were some educators who cautioned that teaching aids are not always required and that their use does not result necessarily in the student acquiring a better understanding of the material being taught.

Pedagogical theories of Rousseau

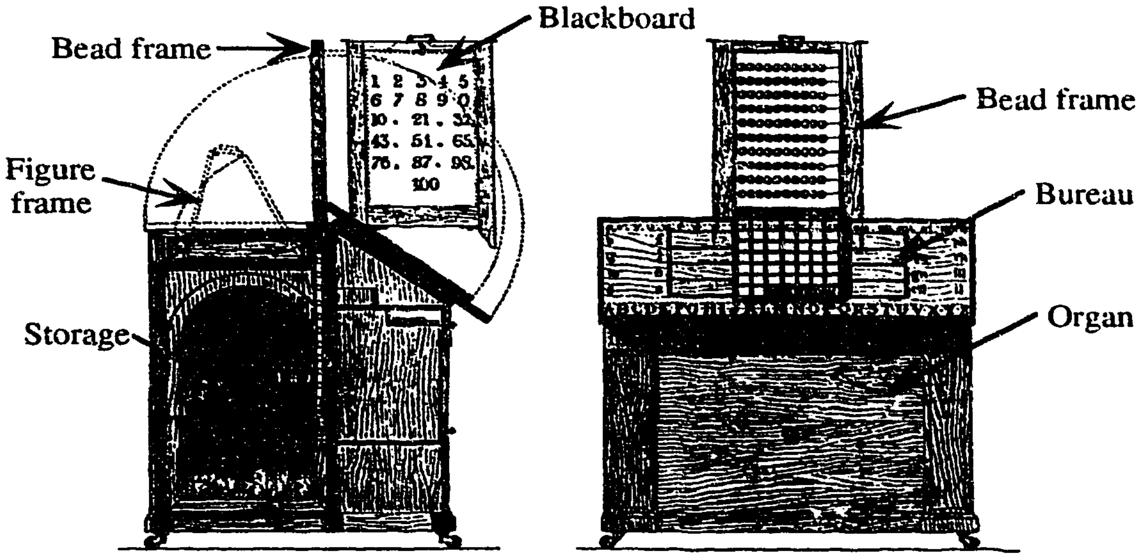
Jean Jacques Rousseau (1712-78) like Locke, also considered the use of teaching aids. It seems that by the time Rousseau began to write about education, other educators were writing about pedagogical methods in general, and also writing about how to improve instruction in particular subjects through the use of teaching aids (Rousseau, 1948). In addition to mentioning the dibstones and other teaching aids advocated by Locke, Rousseau discusses *bureaux,* devices intended to assist the teaching of spelling and reading to young students.

A bureau teaching aid is a type of case containing either cut-out letters, or cards with letters printed on them. The case is designed so that the letters may be arranged along its top. In this way, words can be constructed in a manner similar to the way they are composed on word building frames, described in a previous section. By studying specific words composed on the bureau, a student may be taught to read key words through a controlled process. Rousseau (1948) claims that some educators of his time contend that reading is taught more effectively by using bureaux, than by using traditional methods.

Occasionally, bureaux comprised one part of a teaching aids centre called a *compendium.* Besides including a bureau, compendia could also include diverse equipment such as small blackboards, bead frames, letter charts, storage for other teaching aids and an organ. Figure 31 (after a woodcut in Robson, 1874, p. 398) depicts the cross-sectional and frontal views of one type of French compendium.

Rousseau (1948) however, contends that the main purpose of teaching aids is to increase student motivation to learn particular material. While this may well be a theoretical basis maintained by some educators as a justification for using teaching aids, Rousseau does not provide evidence to support this contention. Based on the assumption that teaching aids are used mainly to increase motivation, Rousseau (1948) submits that there are better approaches, "one which is generally overlooked – it consists in the desire to learn. Arouse this desire in your scholar and have done with your 'bureaux' and your dice – any method will serve" (p. 81).

Rousseau (1948) advocates the use of an actual object or event to teach concepts or information, "As a general rule – never substitute the symbol for the thing signified, unless it is impossible to show the thing itself; for the child's attention is so taken up with the symbol that he will forget what it signifies" (p. 133). Rousseau contends that it is the novelty of the device that is attended to and remembered by the student rather than the concept it represents. In some instances, Rousseau maintains that using a teaching aid will result in confusion because the student will not be able to grasp its significance. To defend his argument, Rousseau describes his observations of the effectiveness of an armillary sphere fabricated from pasteboard, used as a teaching aid for the rudiments of the solar system. Rousseau (1948) states,



Cross-section

Front view

Figure 31. Bureau as part of a compendium

> The confused circles and the strange figures described on it suggest witchcraft and frighten the child. The earth is too small, the circles too large and too numerous... and the thickness of the pasteboard gives them an appearance of solidity... and when you tell the child that these are imaginary circles, he does not know what he is looking at and is none the wiser. (p. 133)

While much of Rousseau's criticism of teaching aids may appear to be based upon anecdotal observations or *a priori* assumptions, there is some modern support for his arguments. Bruner (1964) argues from a cognitive position that for acquired or learned information to be of use to the individual, the information must be encoded or represented in memory in such a way that it is meaningful to the individual. This construct presumes that the individual's sensory organs such as the hands, eyes and ears are not impaired. Bruner (1964) postulates that the method of encoding follows a developmental hierarchy comprised of three main steps, *enactive, iconic, symbolic* (p. 2). If an individual cannot relate the symbolic information of the sphere to either enactive or iconic information already in memory, then it is likely that the symbolic information will be meaningless to the individual. From Rousseau's example, it appears that the symbolic concepts inherent in the armillary sphere were meaningless to the students. Without first explaining the significance of symbols either through enactive or iconic representation, so that the students are able to form a new concept from meaningful concepts already formulated, it can be argued that a teaching aid that uses symbols that are meaningless to the student cannot be understood. It is possible that if the motion of a planet was shown by a mechanical planetarium (an enactive process) and if it were shown that an orbit can be represented by a circle (an iconic representation of an enactive process) then a student might be able to form the symbolic concept that the circular rings of armillary spheres represent orbits of planets. If this sequence is followed, then it is likely that the components of the armillary sphere will be meaningful to the student. An armillary sphere might then be considered an appropriate teaching aid.

In spite of his general criticism of teaching aids, Rousseau (1948) describes several learning activities he devised that are facilitated by using teaching aids. Although his pedagogical method consists primarily of placing students in suitable environments so that they can discover the intended information or concept on their own, Rousseau (1948) contends that some concepts can be best illustrated by using teaching aids. His advocacy of restraint in using teaching aids, however, suggests that their invention and use was widespread in formalized education. Although the validity of Rousseau's general conclusions about teaching aids can be questioned because of his lack of quantifiable evidence, it is important to note that there are examples of other educators who both designed and used teaching aids during this period that, in practice, hindered rather than assisted learning.

Wilderspin's Arithmeticon

Besides using both instructional cards and word building frames, Wilderspin also designed and employed a lettering guide similar to the one designed by Quintilian (McCann & Young, 1982). Wilderspin's guide, unlike Quintilian's, consisted of cursive script instead of block letters. By following the grooves of the guide with a pen or a pencil, Wilderspin maintains that students will learn a correct way of writing script through guided practice (McCann & Young).

Wilderspin also designed an apparatus that could aid in the instruction of arithmetic by being able to show concepts both in a concrete manner (enactively) as well as symbolically. This approach is designed to facilitate the student's formulation of a concept of the process or idea through observing a concrete representation of the idea or process contiguously with the representative abstract symbols. This method is contrary to the prevalent practice of the period which consisted of first presenting abstract concepts and rules, then proceeding to concrete exercises (McCann & Young, 1982).

Wilderspin called his device the *Arithmeticon.* It consists of a specially-designed bead frame and word building frame mounted on a vertical shaft, the bead frame being uppermost. The entire apparatus, intended to stand on the floor next to the teacher, probably stood about 5 feet (1.5 m) high. The bead frame illustrates both quantity and the basic arithmetic functions concretely, while the word building frame shows the demonstrated process symbolically by means of numbers. The bead frame contains twelve horizontal rods that each hold twelve beads. Numbers, placed on the left-hand side of the frame next to each rod, represent incremental increases. In practice, the movement of beads along one row demonstrate either addition or subtraction. By moving the same number of beads along a given number of rows, the principles of multiplication can be shown in a concrete fashion. Figure 32 (after drawing in Wilderspin, 1825) depicts Wilderspin's Arithmeticon. The instrument is illustrating the concept of six multiplied by five.

While the Arithmeticon is intended to make the principles of arithmetic clear to students, Wilderspin's use of the apparatus sometimes confused rather than clarified the concepts and principles he was trying to teach. Instead of demonstrating arithmetical principles using small numbers, Wilderspin frequently used numbers running into the millions. This was probably done by assigning different values to the beads. For example, instead of having a single bead representing one unit, a bead might represent 100. Examples with such large numbers frequently confused his students (McCann & Young, 1982). It may be argued that Wilderspin's use of large numbers were attempts at demonstrating how the principles of arithmetic would apply to large as well as to small numbers. The Arithmeticon could not, however, demonstrate the jump in logic from considering one bead being equal to one unit, to one bead representing 100 units. It does not appear that other educators adopted the use of the Arithmeticon. Although Wilderspin's Arithmeticon was a failure, other teaching aids manufactured during this period embodied enactive approaches to instruction in arithmetic.

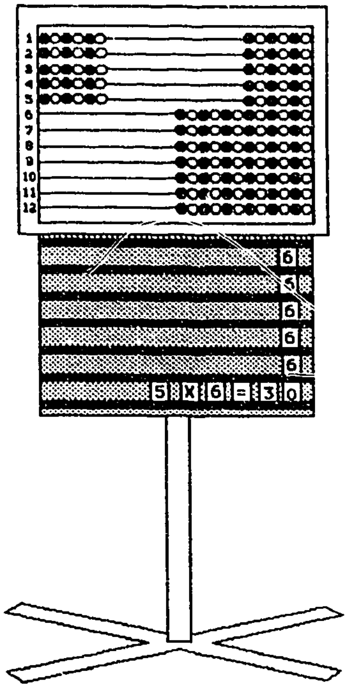


Figure 32. Appearance of Wilderspin's Arithmeticon

Classen's apparatus

One example is a device patented in 1880, by August Classen of Chicago, Illinois. Consisting of a frame similar to Wilderspin's Arithmeticon, Classen's teaching aid uses special counting sticks rather than beads. The counting sticks are placed in seven openings or boxes. The largest opening is usually covered by a blackboard, hinged at the top. The largest opening is also intended to be a storage area for the counting sticks. Figure 33 (after United States Patent No. 234,247, November 9, 1880) depicts the front and side views of Classen's teaching aid for arithmetic.

Classen intended that his teaching aid be used to instruct the principles of fractions as well as whole numbers. For this purpose, he marked divisions on several of the counting sticks (United States Patent No. 234,247, November 9, 1880). While it is possible to illustrate the principles of fractions in this way, the apparatus does not facilitate a top view of the counting sticks, so it is likely that most of the class would not be able to see the marks on the counting sticks. This factor probably contributed to the obscurity of Classen's device.

Siefert's teaching aid

A better attempt at designing an apparatus to illustrate fractions enactively was patented by Henry Siefert of Milwaukee, Wisconsin in 1888. Figure 34 (after United States Patent No. 380,532, April 2, 1888) shows the appearance of Siefert's teaching aid.

Each rod supports a specific number of beads. The first four rods, starting from the top, show: one whole, one half, one quarter, one eighth and one sixteenth. The apparatus is also equipped with a number of indexed charts (shown partially cut-away in Figure 34) to show the various fractions both iconically and symbolically. While the charts may be used independently of the beads, Siefert intends that each be used in conjunction with the

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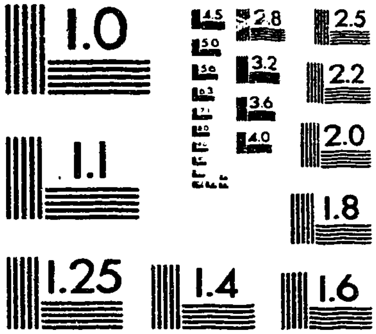

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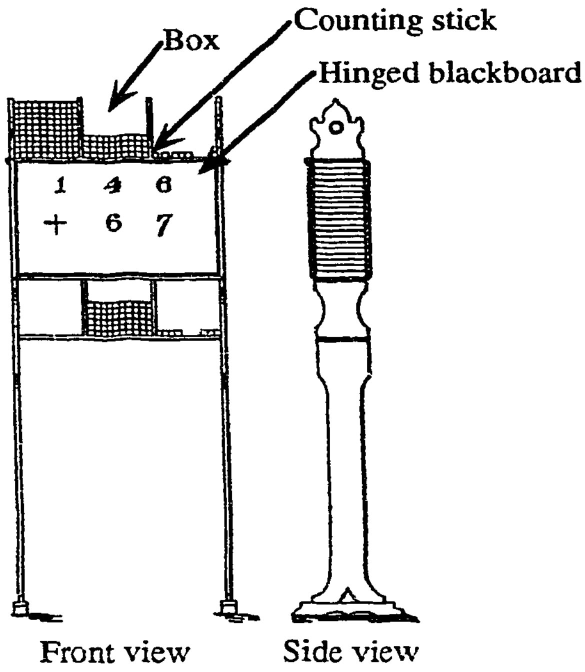


Figure 33. Classen's teaching aid for arithmetic

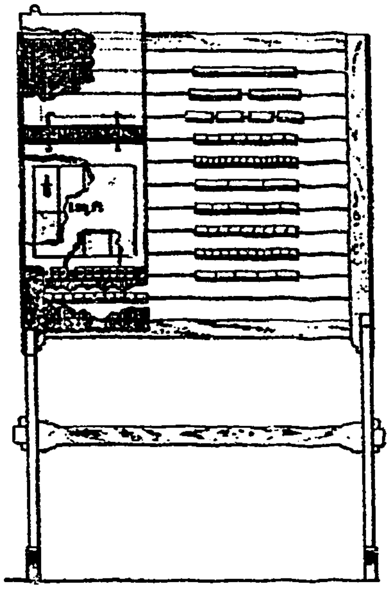


Figure 34. Siefert's teaching aid for fractions

other (United States Patent No. 380,532, April 8, 1888). Siefert's method of instruction bears similarity with Bruner's (1964) ideal method of presenting new material; first enactively, then iconically and finally, symbolically. It is doubtful whether Siefert's teaching aid for fractions was ever manufactured, since the patent documentation notes that no model had been constructed at the time the patent was issued (United States

Patent No. 380,532, April 8, 1888).

Wilderspin's Gonigraph

Although his pedagogical methods were derived ultimately from Locke, Wilderspin was also influenced by Emanuel Swedenborg (1688-1772) a Swedish scientist, pedagogue and religious leader. Swedenborg considered geometry to be important for students to learn, especially the recognition and the identification of the various geometric forms (McCann & Young, 1982).

To assist with instruction of geometric forms, Wilderspin designed a segmented, jointed stick he called a *Gonigraph.* Its appearance is similar to hinged carpenter rules that are still available today. In use, the Gonigraph is manipulated into a variety of geometric forms including polygons and ellipses. Like the Arithmeticon, the success of the Gonigraph as a useful teaching aid was limited by Wilderspin's application of it. Instead of showing simple polygons and other geometric shapes that the students were likely to encounter in their home life, Wilderspin used the Gonigraph to illustrate complex and obscure geometric figures that were difficult to distinguish from simpler figures (McCann & Young, 1982). Although Wilderspin's use of the Gonigraph resulted in confusion rather than understanding, commercial concerns produced and marketed Gonigraphs well into the 1860s, not only in Great Britain and Europe, but in the United States as well (Anderson, 1962). Despite attempts at increasing its use through commercial means, the Gonigraph did not gain the same widespread use as the blackboard. Simpler teaching aids, the ability of most teachers to draw common geometric figures on the blackboard and the cost of the Gonigraph, all probably contributed to its limited use.

By making teaching aids unnecessarily complex, Wilderspin not only made them confusing to students, but he also discouraged their use by other teachers. Other educators continued to use and to devise teaching aids in spite of Wilderspin's problems with those of his own design (Stewart & McCann, 1967). The theories advanced by other notable educators during this period also encouraged the use of teaching aids.

Pestalozzi's theory and pedagogy

Johann Pestalozzi (1746-1827) was a Swiss educator who also subscribed to an earlier theory of pedagogy, that in order for students to understand something, they must formulate a concept of it from a concrete representation. Pestalozzi (1898) states, "There are two ways of instructing, either we go from words to things, or from things to words. Mine is the second method" (p. 2). Pestalozzi's method is centred on what he calls *Anschauung* or sense-impression. Teaching by means of rote is insufficient, therefore. In order to form a concept that is meaningful, a child has to form first a sense-impression of the concept that is to be taught. This sense-impression is acquired through interaction either with concrete objects or with pictures that represent the concept. Pestalozzi (1898) notes that it is the responsibility of the child's mother to provide an appropriate environment for the child to encounter suitable concrete objects and/or photographs before the child reaches school age. In this manner, the parents, and the mother especially, can ensure that the child learns some basic information and skills before going to school, a provision not always found in other pedagogical methods. In the case of teaching the alphabet, for example, Pestalozzi (1898) states,

> These [concepts of the alphabet] should precede the A B C books in order to make those ideas that men express by words clear to the children by means of well-chosen real objects, that either in reality, or in the form of well-made models and drawings, can be brought before their minds. (p. 59)

From this quote, it appears that teaching aids are an integral part of the pedagogical method postulated by Pestalozzi.

Many of the teaching aids he describes are either common articles such as plants and toys, or devices that are similar to those produced earlier by other educators. One example is Pestalozzi's teaching aid for writing. Adopting an approach similar to Quintilian's, Pestalozzi contends that proper writing technique is facilitated by copying appropriate examples of writing. Unlike Quintilian, however, Pestalozzi did not use an engraved guide. Instead, he devised a special copy book to be used in conjunction with a slate. Pestalozzi (1898) assumes that a student learning to write first knows both the alphabet and how to use a slate. The student, without guidance from the teacher, copies the letters and words from the copy book onto the slate, by means of sense-impression, previous knowledge of words and the use of the slate. The student then compares what he/she has written with what is in the copy book. In this manner, Pestalozzi (1898) believes that students can educate themselves practically without the aid of the teacher. Like Quintilian, Pestalozzi maintains that complex skills such as writing are best taught by reducing them to simpler operations. Once a student masters writing the letters and words on a slate, the same exercises are then performed on paper with a pen. Pestalozzi (1898) concurs with Quintilian that learning to form the letters is one discrete skill and that using a writing instrument correctly is another. Pestalozzi (1898) contends that by reducing complex skills to several simpler components, instruction is not only simplified, but is made more coherent to the student.

From the previous discussion, it appears that Pestalozzi's pedagogical methods are derived from a theory of learning that bears similarity to some contemporary theories based in cognitive psychology. Bruner (1964) and Ausubel (1963) for example, stress that information to be learned must be meaningful to the individual. That is, the learner must possess a concept or internalized representation of the information. For example, writing numerals on a blackboard to illustrate addition will be effective only if the students watching have a concept of what the symbols on the blackboard represent. Like Pestalozzi, Bruner (1964) contends that an understanding of a concept must proceed from the concrete to the abstract. This emphasis upon the concrete representation of a concept initially, means that his approach is also facilitated through the use of teaching aids. Moreover, Bruner (1964) states that, "any more highly skilled activity can be decomposed into simpler components, each of which can be carried out by a less skilled operator" (p. 2). While the apparent similarities between Pestalozzi's and Bruner's theories suggest that they both arose from a common knowledge and awareness of psychology, it is important to consider that Pestalozzi's theories are not based upon some stated theory of psychology or learning. Instead, Pestalozzi (1898) states that his teaching method developed as the result of, "vague though vivid feelings, that indeed make my course certain but did not teach me to know it" (p. 56). Pestalozzi (1898) also reports that his pedagogical theory arose from an analysis of his teaching,

> So without knowing the principles on which I was working I began to dwell upon the nearness with which the objects I explained to the children were wont to touch their senses; and so, as I followed out the teaching from its beginning to its utmost end, I tried to investigate back to its very beginning the early history of the child who is to be taught, and was soon convinced that the first hour of its teaching is the hour of its birth. (p. 57)

Pestalozzi's theory was developed on an *a posteriori* basis, since it was constructed from his own observations and findings and later related to contemporary theories of psychology and learning. Bruner's theory, however, was developed largely from an *a priori* basis, since his theory is constructed within the existing rubric of cognitive psychology. The difference in bases does not mean necessarily that one theory is more appropriate than the other.

Although the success of Pestalozzi's pedagogical methods depend upon using a variety of teaching aids, he neither specifies which teaching aids are best suited for teaching particular skills and/or concepts, nor does he judge the appropriateness of specific aids as Locke did. In spite of Pestalozzi's vagueness about which teaching aids are appropriate, his pedagogical methods and theories were adopted by other educators of that time.

Fröbel's law of self-activity

Friedrich Fröbel (1782-1852) noted for his formalization of a pedagogical method now known as *Kindergarten,* devised his method of teaching from the theories of Pestalozzi (Hayward, 1904). Like Pestalozzi, Fröbel's method of teaching employs various teaching aids (Fletcher & Welton, 1912). Developing Pestalozzi's methods further, much of Fröbel's method entails the use of teaching aids by individual students without the assistance of a teacher. For example, once students are made aware of the differences of particular geometric shapes, usually by a teacher, they can then obtain further and possibly more meaningful information by playing with toys made in these shapes (Fletcher & Welton, 1912). This aspect of Fröbel's theory is sometimes referred to as his *law of self-activity* (Morgan, 1913, p. 9). While Fröbel argues that all knowledge does not have to be provided by the teacher, it is important to consider that the teacher is responsible for ensuring that an appropriate environment is maintained and that the students have received sufficient knowledge to make use of the provided teaching aids. Some of the devices Fröbel recommends for use as teaching aids include both rigid and pliable spherical balls, cubes, oblong bricks, cylindrical objects, rectangular and triangular tablets (Fletcher & Welton, 1912). Although Fröbel states that students may learn from such devices without the aid of a teacher, the apparatus he recommends cannot be considered teaching machines, since there is little or no transformation of any input into recognizable, instructive feedback.

It appears that some theories of pedagogy postulated during this time consider the use of teaching aids as an integral component. The apparent trend of educational theories to include the use of teaching aids as an integral part was not confined to traditional classrooms solely. Some individuals used teaching aids with students with mental disabilities.

Séguin's physiological method

Edouard Séguin (1812-80) a physician, psychiatrist and educator, devised a method of instructing mentally-impaired students so that they could perform some recognition and motor tasks independently of assistance from others (Myers, 1913). Séguin refers to his system of teaching as the *Physiological Method* (Myers, p. 538). His method was acclaimed both in Europe and in the United States, and he was hired by different agencies in that country during the 1870s to study various educational systems in the world.

Séguin contends that the successful education of children who are mentally disabled comes about through a blending of medical science and psychology. In consequence of his research, Séguin identified seven discrete areas of instruction that should be considered and addressed in respect to children who are mentally disabled. The seven areas, in turn, comprise his seven-step hierarchy of education, "1) Motor power; 2) the senses; 3) the perceptive faculties; 4) by gymnastics of comparison; 5) the excitement of sentiments and instincts by normal necessities; 6) special excitement of spontaneousness and initiative; 7) incessant provocation to regular action, to speaking, and the exercise of the other faculties then developed" (in Myers, 1913, p. 539). Séguin states that not all mentally-impaired children require special education at level one, and that it is incumbent upon the teacher to ascertain where in the hierarchy natural progress was interrupted. It is contended that once the student's level in the hierarchy is ascertained, then effective instruction can be provided (Myers, 1913).

Séguin claims that his curriculum is derived from activities found in daily use, presumably in a typical environment of the time and locality. Séguin devised a number of teaching aids to assist at each level of the hierarchy. In some instances, his teaching aids are common items used in particular ways. A number of dishes and a wiping cloth, for example, are used to develop muscular patterns and coördination necessary for the washing and drying of dishes (Myers, 1913). Attempting to simplify the complexity of some operations and tasks, Séguin devised teaching aids based on actual articles, but which were simpler in design and construction. He also invented teaching aids not related directly to any common object. These teaching aids are intended to provide practice in particular activities that cannot otherwise be provided using common articles. Examples of such teaching aids include: sets of geometrical inserts and the requisite receptive boards; peg and nail boards for practice in hammering; wooden frames supporting cloth with various fasteners, for practice in fastening articles of clothing; blocks and textured shapes for the development of tactile discrimination; word building frames and instructional cards (Myers, 1913).

Although Séguin claims that his methods are applicable to the education of normal children, few contemporaries in regular schools made use of his teaching aids (Myers, 1913). It was near the end of the nineteenth century that another educator adopted Séguin's methods and modified them for use with children without severe impairments. Unlike Séguin, the influence of this educator and her pedagogical theories and methods prevail in some schools.

Montessori's didactic apparatus

Maria Montessori (1870-1952) is probably best remembered for her pedagogical theories and methods that arose both from her work with children afflicted with psychological disorders and from her reading the works of Edouard Séguin (Montessori, 1912). As in Séguin's *Physiological Method*, teaching aids are an integral part of Montessori's teaching method. Montessori (1912) refers to teaching aids that are congruent with her methods as *didactic apparatus* or *didactic material* (pp. 34-36). While she does specify the devices that comprise her set of didactic apparatus, she does not state whether or not other devices are suitable for use as teaching aids. According to Montessori (1912) the term *didactic material* represents not only apparatus used as adjuncts to teaching, but also items which, when made available by the teacher, can be used by the students to educate themselves. From this explanation, it seems that some didactic material might be considered teaching machines.

While most of her didactic apparatus requires some sort of input by the user, any transformation that occurs is not as the result of the device, but is the result of action by the user. One example is a set of frames Montessori adopted from Séguin. These are intended to help children develop skill in fastening articles of clothing. Each device consists of a rectangular wooden frame with two pieces of cloth tacked to it. The pieces are designed to fit together in the middle of the frame. A different type of fastener is found on each frame, and the student is expected to join the two pieces using the fasteners. Figure 35 (after photograph in Montessori, 1912, p. 201) depicts a frame used by Montessori to aid in the teaching of lacing.

While Montessori maintains that the use of didactic apparatus can result both in a greater understanding of concepts and in a superior mastery of particular motor skills, she also notes that simply using didactic apparatus does not always guarantee successful teaching (Montessori, 1912). Apart from attitudinal biases of the teachers which may affect their teaching negatively, that students are stupid for example, some methods of using didactic material tend to confuse students. In one example, Montessori (1912) describes an arithmetic lesson in addition that was given by a teacher using a bead frame. To capture the interest of the class, the teacher employed two small cardboard dolls to

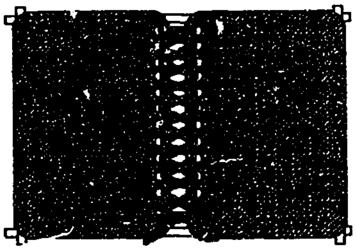


Figure 35. Montessori's teaching aid for lacing

move the beads. The teacher spent considerable time naming the dolls and explaining what each one represented. Montessori (1912) notes that the most memorable part of the lesson was the description of the dolls, not the lesson on the bead frame. In this case, the way the teaching aids were used distracted the students from attending to the main point of the lesson, addition.

As well as the frames for developing dexterity with clothing fasteners, mentioned previously, the didactic material includes: a set of ten graduated wooden cylinders intended to fit within a block with graduated holes; sets of colored cubes, graduated in size, intended for building from largest to smallest; sets of small wooden tablets covered in colored silk, the colors being a selection of the chromatic range of hues; boards to which letters cut-out from sandpaper are attached, intended for the development of tactile recognition of letters of the alphabet (Montessori, 1912). Didactic materials were developed for all areas of the curriculum including physical education. Apparatus for this subject includes: miniature chairs; a portable wire fence to assist children in marching by holding on to the uppermost wire; trampolines and swings (Montessori, 1912). Montessori did not fabricate the didactic material herself. Instead, most of the apparatus was manufactured by the House of Labour of the Humanitarian Society of Milan (Montessori, 1912, p. 169). The didactic apparatus was marketed in many countries including the United States and Canada (Morgan, 1913, p. 70).

Montessori (1912) maintains that the successful deployment of didactic apparatus depends upon the provision of a specialized environment wherein children will have access to a large number of teaching aids. In a manner similar to Fröbel, Montessori developed a sort of *Kindergarten* which she calls *Casa dei Bambini* [Children's House]. Montessori (1912) notes that although her schools and methods seem to resemble those of Fröbel, her pedagogical principles are different, since her method stresses even less intervention by the teacher. Unlike Fröbel and Pestalozzi, who thought it necessary for the teacher to first demonstrate a process or to provide information to students, Montessori (1912) contends that her didactic materials must be used without the interference of a teacher in a trial-and-error or discovery learning environment. An example of what she means is the case of a child who is supposed to learn spatial relationships between holes and cylinders. The child is given a wooden block that has holes of different sizes bored into it, as well as being given a corresponding number of cylinders of different diameters. Without being told, it is anticipated that the child will fit each cylinder into its proper hole. It is also assumed that mistakes will be made. By letting the child do the task without interference, Montessori (1912) maintains that *auto-education* will occur (p. 172). Moreover, Montessori (1912) states,

> The didactic material *controls every error*. The child proceeds to correct himself... This self-correction leads the child to concentrate his attention upon the differences of dimensions, and to compare the various pieces. It is in just this comparison that the *psycho-sensory* exercise lies. (p. 171)

In this manner, it is contended that the child will begin to learn the correct spatial relationship independently of being taught the principles or rules involved.

This example suggests two problems with Montessori's theory. Firstly, there is an implicit assumption that the child will comprehend what to do with the cylinders and the bored block. If the child knows what to do, it may be argued from a cognitive position that the child already possesses some concept of the process. Such a concept may have been learned through observation. If a concept is already present, the child will not be learning the size relationship between objects; that knowledge already exists. Instead, the child will gain practice in applying his/her concept of spatial relationship enactively. While practice is considered desirable by Montessori, it is not the primary intention of the exercise (Montessori, 1912).

Secondly, in the case of a child who makes an error, it is possible that if the child does not comprehend the reason for his/her error, a phenomenon known as *cognitive dissonance* may result. Cognitive dissonance may be defined as the internal conflicts (dissonance) caused by the difference between one's expectation of an event and its perceived reality (cognitions). Festinger (1957) states that cognitive dissonance, a negative drive state which may result in frustration, motivates the individual to act to reduce the dissonance. In the case of the child who expects to place all the cylinders in the block yet ends up with a large cylinder left over and a very small hole might become frustrated. A possible reduction of dissonance might be anger with an attempt at destroying the apparatus. If this occurs, it is doubtful that the child will be using deductive reasoning to solve the problem in the intended way.

Although considerable interest was shown in Montessori's methods initially, a number of factors deterred most educators from adopting her methods and her didactic material. Morgan (1913) evaluating the Montessori method for the Government of Ontario, describes several disadvantages of her method. A major disadvantage noted is that much of the didactic apparatus and the skills they provide practice in are largely unnecessary with most Canadian children, who appear to know the concepts inherent in the devices by the time they reach school age. Morgan (1913) states, "there would be no justification for taking up the time of our junior pupils with the large amount of meaningless didactic materials provided in the system" (p. 70). The high cost of the didactic apparatus seems to be another major disadvantage of the Montessori method. In North America, the apparatus sold for $50.00 in 1912 (Morgan, 1913, p. 70). It is important to note that the monthly salary of many teachers in Canada at this time was below $50.00 (Alberta Department of Education, *Annual reports*, 1912-1914). Morgan (1913) also criticizes the efficacy of self-education. Others such as Dent (1914) and Graves (1914) also question the efficacy of the Montessori method and also query whether it is a serious educational movement or whether it is simply a passing fad.

While Montessori did design a method of pedagogy wholly dependent upon teaching aids, the high cost of the method and the superfluity of much of the didactic apparatus seems to limit the deployment of her method. To be sure, there are schools in North America as well as Europe that offer instruction according to Montessori's methods, but a general adoption of her methods has not taken place. Apart from the development and promotion of new theories of pedagogy, there are other factors that affect the prevalence and the use of teaching aids. These factors will be described and discussed in subsequent chapters.

Teaching machines for children

Why were teaching machines largely absent from childhood education during this period, since they appear to have existed in the past and since they seem to be ideally suited to Montessori's method? While there can be no definite answer because of a lack of evidence, it seems that three main factors limited the development and the use of teaching machines during this period. First, it appears that teaching aids were congruent with most pedagogical approaches of the time. Where it is expected that the teacher is an instrumental part of pedagogy, a teaching machine would not be considered appropriate. One of Morgan's (1913) criticisms of Montessori's use of teaching aids in a self-instructional way, is that they tend to exclude the input of the teacher, thus creating a process that, according to Morgan, is not truly educative. Second, most of the teaching aids in use during this period seem to be intended to reduce complex concepts or operations into simpler discrete elements. Apparatus that adds to the complexity of the operation or concept, rather than simplifying it, is not likely to be considered appropriate. Third, technical knowledge may not have been available to those educators who designed instructional devices. It is doubtful, for example, that Montessori knew enough about materials and available technology to design a teaching machine. The idea of teaching machines, while in an apparent eclipse, had not disappeared entirely. At least one teaching machine was produced during this period for teaching the rudiments of arithmetic.

Van Der Veer's rotary teaching machine

In 1846, Benjamin Van Der Veer, of Clyde, New York, patented a tubular device that could be used to teach basic arithmetic without the aid of a teacher (United States Patent No. 4,632, July 14, 1846). The apparatus consists of a specially prepared sheet of numbers that is attached to a wooden tube or dowel. The dowel or tube fits into a larger cardboard tube with several openings cut into it as well as being marked along the top edge with a sequence of numbers from 1 through 12. Two caps complete the assembly. Both caps are designed to fit onto the inner tube. The top cap contains numbers that coincide with the numbers along the top of the larger tube. The bottom cap, which is glued to the inner tube or dowel, is intended to be used as a handle by the user. Figure 36 (after United States Patent No. 4,632, July 14, 1846) depicts the components of Van Der Veer's teaching machine as well as a view on how it is to be held in use.

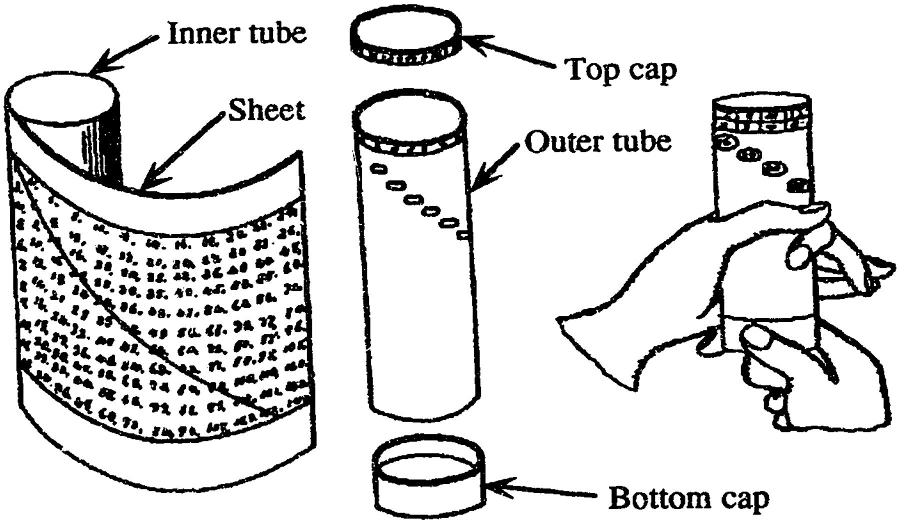


Figure 36. Van Der Veer's rotary teaching machine

In practice, the bottom cap is rotated so that the numbers of the top cap are aligned with the numbers drawn on the outer tube. The machine can be set-up for any one of the four basic arithmetic functions. Assuming that the machine is arranged for multiplication, the number appearing in the opening in outer tube directly below the aligned numbers represents their product. For example, if a 9 on the top cap is aligned with a 3 on the outer tube, then the number displayed in the opening below is 27. While it may seem that this device is nothing more than a calculator, the openings in the outer tube are arranged so that each subsequent product is visible. In this way, an incremental progression is discernible, a phenomenon not common with most calculators. Although initial instruction by a teacher is required, it is possible to gain further knowledge by using Van Der Veer's machine. The input consists of the user rotating the caps. The transformation is the movement of the top cap and the sheet attached to the inner tube. The feedback consists of the numbers visible in the openings of the outer tube. It is not known whether or not Van Der Veer's machine was produced commercially, or whether it was well received by educators.

Armillary spheres

It has been mentioned in a previous section that the use of armillary spheres as teaching aids was criticized by Rousseau (1948) because the concepts they embody tend to be too complex for most pupils to grasp. In spite of such criticisms, armillary sphere-type teaching aids continued to be developed throughout this period. One example, that attempts to overcome the complexity noted by Rousseau, is the device designed by Anne Gregory of London, England, in the early 1890s (United States Patent No. 501,136, July 11, 1893). Instead of using rings to represent the paths of celestial bodies, Gregory employed drawings of stars on a glass sphere. A model of the earth, enclosed within, could be rotated from outside the sphere. By looking at the relative position of the stars and particular continents, enhanced by means of a lamp which casts shadows of the star drawings onto the continents, the observer can see why stars seem to rise and set. Figure 37 (after United States Patent No. 501,136, July 11, 1893) shows the general appearance of Gregory's device, including a lamp.

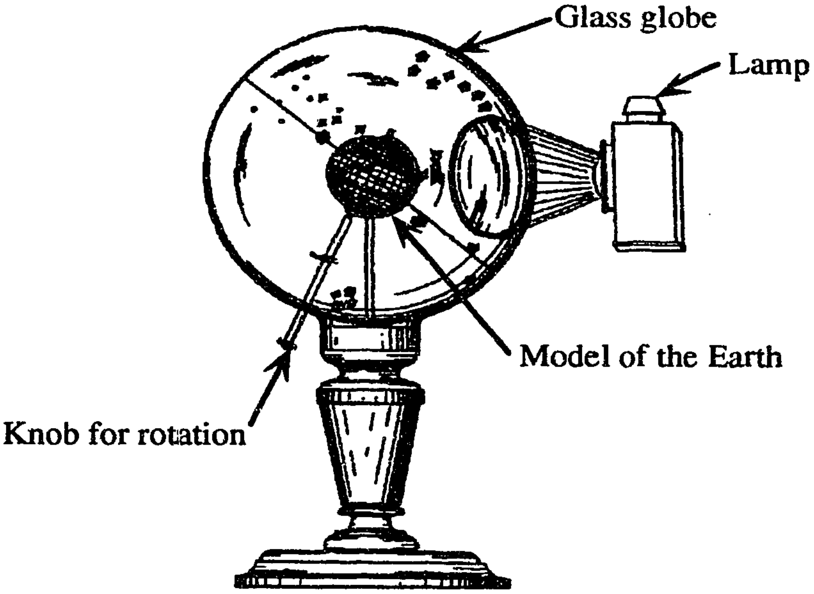


Figure 37. Gregory's armillary sphere-type teaching aid

Although Gregory's apparatus was designed as a teaching aid for demonstrating aspects of both astronomy and geography, it may also be used as a teaching machine. While the description of how the device is to be used is vague, it is possible that the device was intended to be used by the students themselves. The input consists of moving the earth model, and possibly, holding a lamp so that its light shines through the glass globe onto the earth model. The transformation would be the movement of the earth and the consequent movement of the relative position of the stars. The instructional feedback would be the realization of why the stars seem to move in the firmament.

The use of instructional apparatus during this period was not limited to children and to young learners.

Teaching machines and teaching aids for adults

Schickard's device

Wilhelm Schickard (1592-1635), who taught at the University of Tübingen, Germany, is noted for his work in astronomy and mathematics (Williams, 1985). Among his inventions is a mechanical teaching aid for astronomy. Although the device probably has not survived, a depiction of it appears in a portrait of Schickard, dated 1632, now housed in the University of Tübingen. The painting appears to be somewhat inaccurate, since the teeth on two spur gears are depicted in such a way that they could not mesh with the cogs of adjacent lantern gears. The apparatus consists of a cubic metal frame that houses a series of gears and shafts. An oblong handle is attached to the frame by means of an L-shaped metal bracket. Representations of the sun, earth and the moon are each attached to a shaft. It appears that the representations are in the form of disks. The shaft supporting the moon disk also supports a triangular shape that is either attached to the moon disk or is mounted directly behind it. The triangular shape may represent the shadow of the earth. The representations of the earth and the moon also appear to be mounted to their shafts in such a way that they would appear to wobble when the shafts are rotated. Figure 38 (after detail in portrait of Schickard, 1632) depicts the appearance of Schickard's instructional device as interpreted by the author. It should be noted that the number of teeth and cogs of the gears in this figure are not shown accurately, since their depiction in the portrait is not clear.

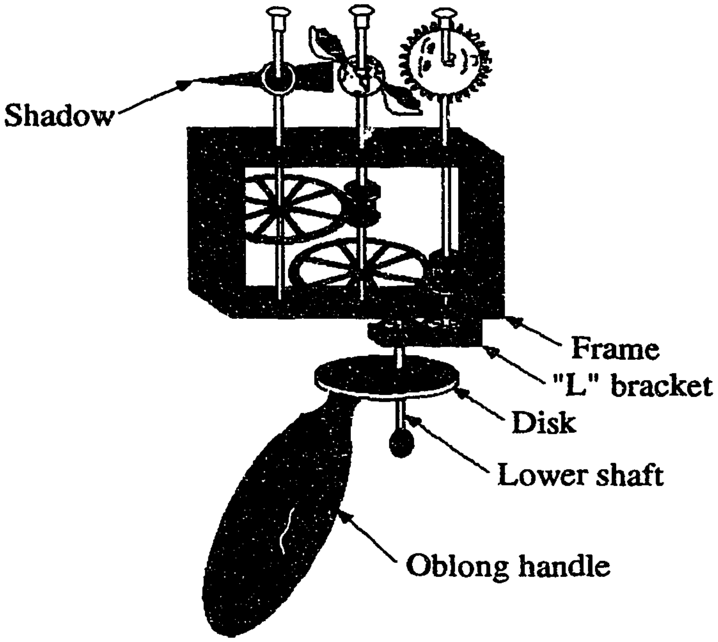


Figure 38. Schickard's instructional device

There is controversy as to what this aid is supposed to depict and how it was operated. King and Millburn (1978) believe that the apparatus is a model of the Copernican system of the solar system, showing how the earth and the moon revolve about the sun. According to King and Millburn (1978) the handle is held in one hand while the frame is rotated by the other. In this fashion, the earth and the moon are be shown revolving about the sun while each is rotating on its own axis. There are a number of problems with this explanation. Firstly, if the frame was intended to spin around the handle, it would not have been necessary to attach the handle to the frame by means of an L-shaped bracket; the handle could have been attached to the frame directly. Secondly, if the device was intended to show movement of the solar system according to Copernican theory, why are only the earth and the moon present in addition to the sun? The omission of the other known planets, especially Mercury and Venus, provides an incomplete and inaccurate picture of the solar system at best, or confuses the student at worst. Thirdly, if movement according to Copernican theory is the intended function of the device, it is not necessary for the moon to rotate. The depiction of lunar rotation is not only inaccurate, but unnecessary to the demonstration. Fourthly, including of a representation of the earth's shadow on the moon is superfluous if the device is intended to show basic Copernican motion primarily.

A close examination of the portrait reveals parts of the device that King and Millburn (1978) fail to consider. It also appears that the artist omitted two gears that are included in Figure 38. While the main support for the apparatus is the oblong handle, it is not attached directly to either the frame or to the L- shaped bracket. Instead, the handle is attached to a metal disk located below the L- shaped bracket. A shaft that extends above the disk and probably below it as well is visible. Above the disk, the shaft passes through the L- shaped bracket and into the frame. Since the frame is not resting on the disk, it is likely that the shaft passes through a tube that joins the disk to the L- shaped bracket. The existence of the shaft below the disk is inferred. In the portrait, Schickard is holding the handle in his right hand. The thumb and forefinger are not wrapped around the handle. Instead, they seem to be gripping something, possibly a small knob. If this is the case, it is likely that the shaft extends below the disk and that power for the gear train is transmitted through that shaft. The shaft is not aligned with any of the three shafts in the frame, so it follows that there must be additional gears present. The most likely location for these is within the bend of the L- shaped bracket. King and Millburn (1978) note that the L- shaped bracket appears to be attached to the frame directly beneath the shaft supporting the sun. Through perspective, it is likely that the artist misplaced the bracket, and that it is actually located slightly to the right of the sun shaft. If this reconstruction is correct, both the operation of the device and its use differ from the explanation given by King and Millburn (1978).

Instead of being a teaching aid for Copernican theory, it is likely that Schickard's device shows the conditions necessary for the occurrence of a lunar eclipse. In operation, the apparatus is held in one hand with the thumb and forefinger used to turn the lower shaft. The rotation is transmitted to the three main shafts via the gears. This motion not only causes the three depictions to rotate, but it also causes them to appear to tilt back and forth. The rotation of the moon shaft also turns the shadow, so that it becomes invisible. The shadow reappears only when the earth is once again aligned between the sun and the moon. The wings attached to the earth probably help to show that the earth tilts as well as rotates on its axis.

Schickard's device was undoubtedly used as a teaching aid, given its depiction in the portrait, but it could also have been used as a teaching machine. A student, after receiving some theoretical instruction, could observe in a tangible way the conditions that produce a lunar eclipse. The input to the device is the movement of the lower shaft. The transformation entails the planetary disks moving to new positions, and the feedback consists of the depictions attaining new positions. Since the shadow depiction is only visible when the moon, earth and sun are all aligned, then the student could learn from the device that a lunar eclipse will occur only if this condition exists.

The pedagogical superiority of three-dimensional teaching aids over two-dimensional drawings is demonstrated through considering the difficulty in ascertaining the actual configuration and function of Schickard's device from the representation in the portrait. This phenomenon may be a reason why three-dimensional teaching aids as well as teaching machines were gaining widespread popularity with educators.

Development of devices already in use

Planetary teaching machines

It is noted in a previous section, that the use of mechanical planetaria as both teaching aids and teaching machines continued through this period. Most early examples of these devices that we are aware of, are mechanically elaborate and fragile. They were usually fabricated of expensive materials and were sometimes intended to be works of art as well. It is likely, therefore, that their use was limited to those individuals and institutions that could afford them. By the mid 1600s several types of mechanical planetaria were made (King & Millburn, 1978). While some were complex mechanically, others were comparatively simple affairs, intended to depict the movement of only a few celestial bodies. Inexpensive materials were also used in many cases. Elaborate devices, intended to show movement of all known planets of the solar system are referred to generally as *planetaria*. Certain planetaria, which were first fabricated in the early 1700s, initially for Charles Boyle, the fourth earl of Orrery, are called *orreries* (King & Millburn, 1978, p. 154). Considered to be a distinct type of planetarium, orreries are designed to show axial movement of the earth as well as the relative motion of the planets around the sun (Gunther, 1923b; King & Millburn, 1978). Other types of planetaria usually do not show the diurnal rotation of the earth. For the purposes of this account, orreries as well as other varieties of planetary mechanisms will be considered as a group. Some planetary machines are constructed so that their mechanism is driven by clockwork. Such devices cannot be considered teaching machines since there is no provision for user input, except for winding the mechanism and setting the position of the planets.

Most planetary machines, following Copernican solar system theory, conform to a basic design and appearance. The sun and the planets are represented by spheres of different sizes and they are supported above the mechanism either by means of slender tubes or by thin wires. The appearance of the remainder of the machine is dependent both on the configuration of the operating mechanism and the extent of the housing. Some machines contain an array of concentric spur gears, each of which supports a planet. The gears are usually hidden from view by means of concentric plates placed above the gears. The housing, besides containing the mechanism, also holds a crank so that a user may cause the mechanism to function. Another type of machine employs a series of coaxial tubes emerging from the top of the housing to transmit motion to the planet spheres by means of attached support wires. Depending upon how elaborate the housing is, the support wires and the coaxial tubes are either exposed to view, or they are concealed. The operation of either version is the same and of little consequence to the user. Figure 39 (after several examples of planetary machines) provides a basic view of a planetary machine.

Specialized machines

Some planetary machines were constructed to illustrate a particular concept of astronomy, or to illustrate some astronomical theory in a tangible manner. These machines were produced from the premise that the user already possesses some knowledge or concepts of astronomy as it was then understood. Support for this view is found in a letter of David Rittenhouse (1732-96) an American scientific instrument maker and a

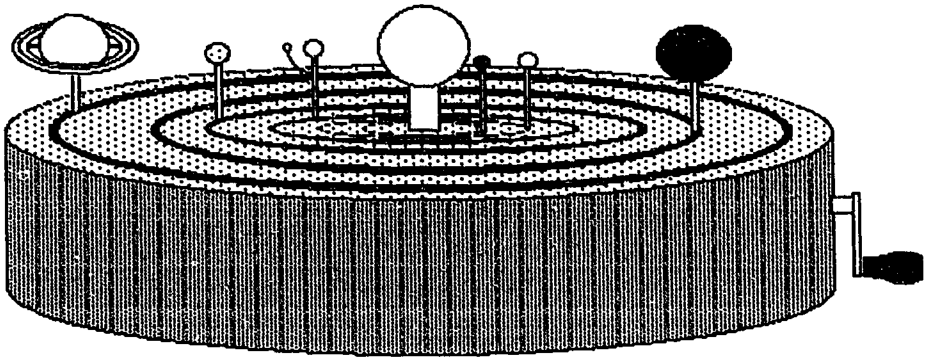


Figure 39. Typical appearance of a planetary machine

professor of astronomy at the University of Pennsylvania. In describing one of the planetary machines he made, Rittenhouse states,

> I did not design a Machine, which should give the ignorant in astronomy a just view of the Solar System: but would rather astonish the skilful and curious examiner, by a most accurate correspondence between the situations and motions of our little representatives of the heavenly bodies, and the situation and motions of these bodies, themselves. (in King & Millburn, 1978, p. 270)

One example of a specialized planetary machine is the device constructed by the Dutchman Christiaan Huygens (1629-95) in 1682. This machine is designed to show a *birds-eye* or *God's-eye* view of the Keplerian motion of the planets as they revolve around the sun. While Keplerian motion entails planets travelling in elliptical orbits, it is difficult to reproduce such motion using gears, given the technology available at that time. Instead of showing true Keplerian motion, Huygens constructed the device so that the orbits are arranged eccentrically to one another. Hemispherical representations of the planets travel within these orbits. The internal gearing is arranged so that the orbital velocity of each planet varies at both the apehelion and the perihelion. In this manner, the machine simulates Keplerian orbits accurately without the need of an elliptical track (King & Millburn, 1978). While the machine is equipped with a clockwork mechanism that can move the planets in real time, there is also provision for moving the planets manually by means of a crank. One turn of the crank represents one year of planetary motion (King & Millburn, 1978). Figure 40 (based on descriptions of Huygen's planetarium) depicts the basic appearance of Huygen's planetary machine in schematic form.

When used in the manual mode, this machine can be used both as a teaching aid and as a teaching machine. As a teaching aid, the machine may be used to show: relative motion, Keplerian motion, velocity changes at the apehelion and the perihelion and time duration necessary for the alignment of particular planets. If it is to be used as a teaching machine, some knowledge of what the device is supposed to represent is required of the user. By turning the crank (input) the user causes the planets to revolve (transformation). The instructive feedback consists of the user noting the apparent elliptical nature of the orbits as well as the fluctuations in orbital velocity. In this manner, a student can learn the fundamental features of Keplerian motion from the machine at his/her own pace. Depending upon the level of knowledge of the user, the machine can also be used to teach the concept of relative motion as well as the concept that the solar system is driven by a single force, possibly divine (King & Millburn, 1978).

Other planetary machines intended for instruction in particular aspects of astronomy include *cometaria*, which are designed to illustrate the elliptical path of a comet as it

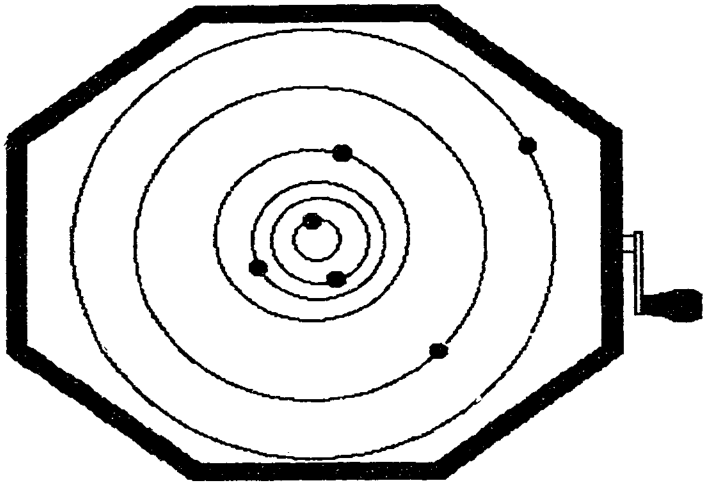


Figure 40. Schematic appearance of Huygen's planetary machine

travels around the sun (King & Millburn, 1978). Like the planetary machines mentioned previously, cometaria may be used both as teaching aids and as teaching machines. In some instances, planetary machines are employed to demonstrate theoretical suppositions in a tangible way. One example is the apparatus designed by James Clerk Maxwell (1831-79) to explain the composition and the change in position of the rings of Saturn.

The apparatus, constructed in 1857, consists of two wheels mounted on a horizontal crankshaft. The wheels are arranged on the crankshaft so that they are on the same plane. They are also placed so that their relative motion is out of phase. Thirty-six small cranks connect the circumferences of each wheel, and small ivory spheres are placed on one end of each crank (Gunther, 1937). When the main crankshaft is rotated, the relative motion of the wheels cause the ivory spheres connected to the smaller cranks to revolve rapidly, creating an illusion of a solid ring. The movement of the wheels also create the illusion of the ring changing position. By using this apparatus as a teaching aid, Maxwell was able to illustrate both how his theory worked and also how it conformed to contemporary understanding of physics.

Pedagogical implications

The apparent pedagogical advantages of using planetary machines for teaching aspects of astronomy became known widely. In addition to British universities, educational institutions in most other European countries employed planetary machines as teaching aids, and possibly as teaching machines as well (King & Millburn, 1978). Harvard College, and later other American institutions and individuals, either acquired planetary machines or had them fabricated. At least one German planetary machine was given to the emperor of China in 1793 and later several British examples were presented as well (King & Millburn, 1978; see also Chapter III).

A British journalist writing in 1713, notes that the speed at which one comprehends the concepts of astronomy is increased through the use of planetary machines, "That which would have taken up a Year of Study to come at a familiar Apprehension of it, is communicated in an Hour..." (in King & Millburn, 1978, p. 154). The journalist's account is not clear as to whether the device was being used as a teaching aid or as a teaching machine. Although rapid learning was noted in the past as an advantage of using planetary machines instead of lectures, the use of such machines did not become widespread generally. King and Millburn (1978) note that by the mid 1760s, many

English universities suffered from a lack of permanent professors, while student enrollment continued to rise. The few professors on staff probably delegated some teaching duties to advanced students, or they employed instructional devices to reduce the time necessary for teaching. While King and Millburn (1978) imply that the instructional devices were used as teaching aids, it seems that they could also have been used as teaching machines, given the apparent lack of time a professor had available for student questions and problems. Although this situation was probably not as acute in the rest of Europe or in America, the number of planetary machines being produced did increase in these locations (Bedini, 1964).

While it is likely that large planetary machines were used solely as teaching aids, it seems probable that smaller examples were used as teaching machines, since their size does not facilitate their use in classes containing more than three or four students. There is some support for this view. William Jones (1763-1831) an English manufacturer of planetary machines, produced a variety of simple devices that were available at minimal cost. In a booklet intended for advertising purposes, Jones states that at least one such machine was purchased by a teacher from Northampton, John Ryland (1723-92), "for the use of his pupils" (in King & Millburn, 1978, pp. 206-207). It is important to note that Jones does not state whether it was for the use of Ryland as a teaching aid, or whether it was for the use of his students as a teaching machine. Jones also describes the improvements he made, so that the new version, "recommends itself to the Public for Simplicity and Cheapness, particularly to Masters and Governesses of Boarding Schools, Private Tutors, &c" (in King & Millburn, 1978, p. 207). Additional evidence to support the view that planetary machines may have been used as teaching machines, is found in a criticism made of poorly-fabricated planetary machines. The account, from the 1830 edition of the *Edinburgh Encyclopaedia* complains that many small planetary devices are so poorly designed and constructed that the orbital velocities of planets close to the sun are slower than those of planets located farther out. This condition results in the outer planets overtaking those located closer to the sun, "hence the machine becomes nothing more than an expensive toy, calculated to mislead rather than to instruct the juvenile student in astronomy" (in King & Millburn, 1978, p. 336). If such devices were intended to be used solely as teaching aids, the faulty construction would not be of such great concern, since the demonstrator could readjust the machine, or explain the error as it occurred. If these devices were used as teaching machines, however, then the user would be shown an inaccurate representation of planetary movements. The user would learn from the machine, but the information would be erroneous and misleading.

From the discussion in the previous paragraph, it is apparent that the use of planetary machines was no longer restricted to the rich and to universities. Demonstrations intended for the general public were also given at frequent intervals in most European countries (King & Millburn, 1978). There is additional evidence to show that planetary machines were also used to instruct children. An account written by William Stuckley in 1752, notes that a planetary machine in the possession of archdeacon Cumberland, rector of a church near Peterborough, England, was played with by his children. Although the device was eventually ruined by them, it is likely that they did learn something from it before it was destroyed (King & Millburn, 1978). More convincing evidence exists in a painting by Joseph Wright. The work, entitled *The Orrery,* dating from about 1764, depicts a demonstration being given using a large planetary machine (in King & Millburn, 1978, p. 166). Besides several adults, there are three children shown attending to the device. It is likely that the machine was being used as a teaching aid in this instance.

Logic demonstrator

The pedagogical theory that contends that an abstract concept can be more easily understood by demonstrating it tangibly, was used by some eighteenth and nineteenth century educators to teach concepts and rules of logic. One example is Charles, third Earl of Stanhope (1753-1816) who designed a device called the ***logic demonstrator***. The device, believed to have been constructed in 1777, is intended to demonstrate the principles of the logic of probability and the logic of certainty. A contemporary states that the device may also be used as calculator for the two types of logic (Gunther, 1923a).

The apparatus consists of a 0.75 inch (19 mm) thick rectangular mahogany block approximately 4.5 inches (114 mm) long by 4 inches (102 mm) wide that supports a brass plate with a printed card affixed to it. Two sliding pieces, called sliders, are required to complete the apparatus. One slider consists of a slender mahogany frame which supports a piece of transparent, red-coloured glass. This slider is located on the right-hand side of the apparatus and may be slid in and out This slider cannot be removed from the device. The other slider is wooden and was painted grey. This slider can be inserted into grooves in the top or the left-hand side of the device (Gunther, 1923a). Figure 41 (after photograph in Gunther, 1923a, p. 126) shows the appearance of Stanhope’s logic demonstrator.

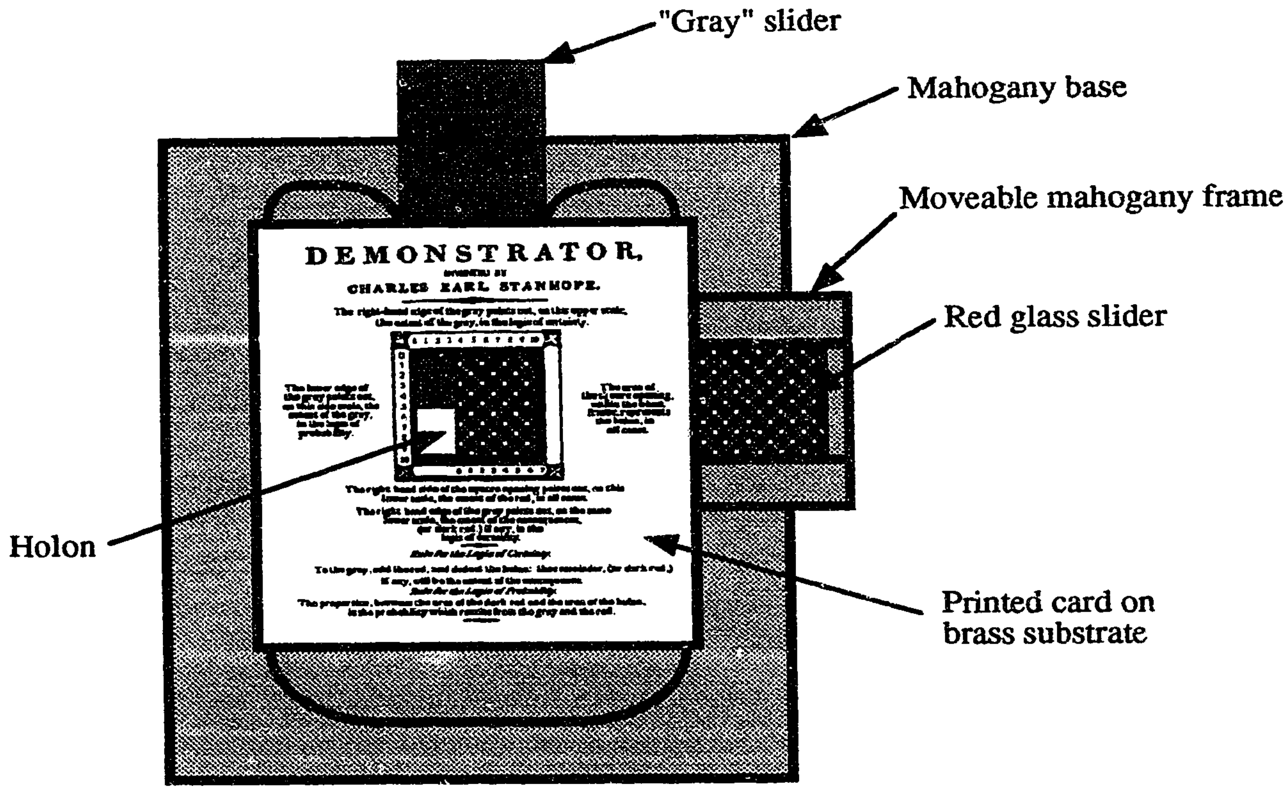


Figure 41. Appearance of Stanhope’s logic demonstrator

The two sliders intersect within a square opening in the card and brass frame. This opening is called the ***holon*** and it is within the holon that the apparatus demonstrates the two rules of logic. If the grey slider is inserted into the grooves on the left-hand side of the apparatus, the device is configured for demonstrating the logic of certainty. If the slider is inserted into the opening at the top of the apparatus, the device will demonstrate the logic of probability (Gunther, 1923a). The arrangement of the sliders is such that the grey one is always below the red. In this manner, one may observe a colour change in the red slider when the grey is present. In operation, the area of the holon not obscured by either slider will indicate the result of the logical problem in a tangible manner.

It has been mentioned previously that this pedagogical approach of demonstrating abstract concepts tangibly so that they can be understood by the learner, was employed by earlier educators, and that this method also bears similarity to some modern cognitive pedagogical approaches, such as those of Bruner (1964). While Stanhope's logic demonstrator did function as intended, knowledge of the device was not widespread. Other educators of this period also developed ways of demonstrating logical principles in concrete ways.

Jevons' pedagogical method

W. Stanley Jevons (1835-1882) was a professor at Owens College, which now comprises a part of the present-day University of Manchester. One of Jevons' areas of interest was logic, specifically the logical method devised and codified by George Boole (1815-1864) that is known variously as *Boolean logic* or *symbolic logic*. Boolean logic entails the algebraic manipulation of particular symbols and logical operators that are used to represent conditions and operations which, in turn, can be applied to a myriad of objects and states. Currently, the principles of Boolean logic underlie the basic operation of most digital computers and other digitally-based devices, in the form of logic gates that produce one of two possible output states at one time; *on* or mathematical 1, or *off* or mathematical 0. During the 1860s, however, few individuals either understood Boolean logic or appreciated its potential uses (Jevons, 1870).

Considering how abstract concepts were taught in the past, Jevons (1870) notes that throughout most of history mechanical devices were employed to demonstrate abstract concepts tangibly and to reduce their complexity into simpler elements. Jevons (1870) cites several examples, "I may mention astronomical clocks, mechanical globes, planetariums, slide rules, &c" (Jevons, 1870, p. 497). Jevons concludes, therefore, that the best way to teach Boolean logic is to demonstrate the principles in a clear and concrete manner. A teaching machine or a teaching aid is ideal for this purpose.

Through his own admission, Jevons was not aware of Stanhope's logic demonstrator when Jevons began to teach Boolean logic (Jevons, 1877). Jevons acknowledges that others had either conceived of or had constructed computing devices or logical machines before him. The gear-driven machines of Charles Babbage (1792-1871) are mentioned as well as the theoretical computer proposed by Alfred Smee in 1851 (Jevons, 1870). While Smee's device was never constructed, portions of Babbage's machine were. Neither Smee's theoretical model or Babbage's gear-driven devices operated according to the principles of Boolean logic, and neither was constructed for the purpose of teaching.

Logical abacus

To assist his teaching of Boolean logic, Jevons used a teaching aid initially, a specially-constructed abacus. Jevons considered the use of teaching aids necessary because considerable calculation was required at that time to simplify complex Boolean expressions. Describing the abacus, Jevons (1877) states that it, "consists of a common school blackboard placed in a sloping position and furnished with four horizontal and equidistant ledges" (p. 104).

In the manner of word building frames, the logical abacus is designed to support, on the horizontal ledges, thin wooden rectangles that have various Boolean letters and operational symbols printed on them. The wooden rectangles also support short steel pins that are inserted into holes either near the top or near the bottom of each rectangle. If the letter on the rectangle is a positive term, an *A* for example, then the pin is placed in the upper hole. Negative terms, represented by Jevons as lower-case italic letters such as *a*, require that the pin be placed in the lower hole of the corresponding rectangle. The placement of the holes differed slightly for each letter used (Jevons, 1877).

To demonstrate the simplification of a complex expression, Jevons first constructed the expression on the uppermost ledge. Using a ruler placed beneath the pins, Jevons could then lift and remove all rectangles showing a particular letter. These rectangles were placed onto the next lower ledge. This action represented the first step in reducing the expression. The process could be repeated for other letters, by placing them on subsequently lower ledges, if further reduction of the original expression was required (Jevons, 1877). In this manner, a student could see each step of the operation. Jevons (1877) states that he used the logical abacus as a teaching aid rather than as an aid to calculation, "I have found [the logical abacus] useful in the lecture-room for exhibiting the complete solution of logical problems" (p. 104). In spite of its evident success in demonstrating the principles of Boolean logic in a concrete way, Jevons was not satisfied with this type of teaching aid.

Jevons' logical machine

Contending that logical operations can be demonstrated better by means of a machine, Jevons (1877) states,

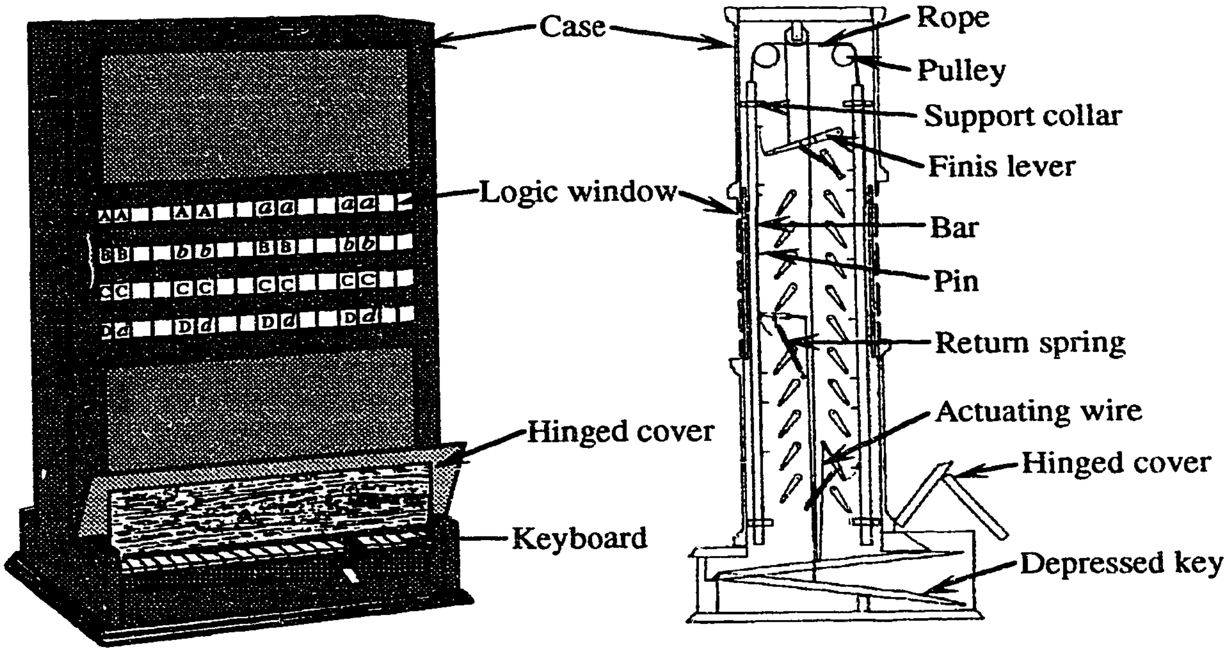
> Although the Logical Abacus considerably reduced the labour of using the Indirect Method [of reducing complex Boolean expressions], it was not free from the possibility of error. I thought moreover that it would afford a conspicuous proof of the generality and power of the method if I could reduce it to a purely mechanical form. (P. 107)

While the technology available to Jevons was not sophisticated by current standards, the means were available to construct such a machine. Jevons (1877) notes, "The Logical Abacus soon suggested the notion of a Logical Machine, which, after two unsuccessful attempts, I succeeded in constructing in a comparatively simple and effective form" (p. 108).

The logical machine consists of a 21-key keyboard and a system of bars, wires, levers and springs that are housed in a wooden case. A series of openings permit both a class and the user to observe various letters that represent Boolean expressions. Figure 42 (after illustrations in Jevons, 1877) shows the general appearance of Jevons' logical machine as well as a cross-sectional view to show the major components of the mechanism. It should be noted that most of the actuating wires and return springs are omitted for clarity.

Power for the machine comes from the action of pressing keys. In operation, the user presses the keys corresponding to the elements of the Boolean expression. Each key is connected to a paddle-shaped lever by means of a copper actuating wire that is also connected to a short brass arm attached to the lever. A return spring is also attached to each lever (see Figure 42). The machine also contains 16 wooden bars arranged vertically in two rows inside the case. Half of the bars are located at the front of the machine, while the remainder are located at the rear. Ropes connect the top of each corresponding front and rear bar through a system of pulleys. The bars are held in place by wooden support collars located near the top and bottom of each bar. Each bar supports a series of small brass pins. These pins represent the logic of each bar. A number of cards printed with Boolean symbols are attached to each wooden bar so that when the bars are moved either up or down, particular symbols or blanks will be made visible through openings or windows cut into the front and rear of the case.

The action of pressing a key causes a particular lever to pivot upwards. Depending upon the condition of the machine, the lever will either engage or miss one or more pins located in the wooden bars. If a pin is engaged, then the bar it is attached to will be moved up by the throw of the lever. This action also causes the corresponding bar on the other side of the machine to move down by the same distance. These actions result in



External view

Cross-section

Figure 42. External and cross-sectional views of Jevons' logical machine

changes to the display in the logic windows. Each key represents a particular Boolean symbol or operand. The keys were not labeled on the actual machine. Figure 43 (after illustration in Jevons, 1877, p. 109) depicts the lay of the keys.

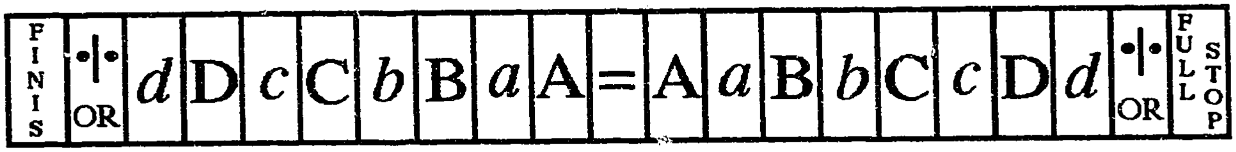


Figure 43. Key layout of Jevons' logical machine

It should be noted from Figure 43, that the symbol Jevons uses for indicating the OR function is different from the symbol used commonly at the present time.

The machine is designed to perform Boolean functions up to a maximum of four positive terms and four negative terms. While Jevons acknowledges that some Boolean operations require more terms, he considers such elaboration superfluous for the purposes of teaching Boolean concepts (Jevons, 1870). To enter a Boolean expression, one must first press the particular letter keys that correspond to elements on the left-hand side of the equal sign or *copula* as Jevons refers to it. If the logic is AND, just the letter keys need to be pressed. If OR logic is being used, then the OR key must be pressed in between presses of the letter keys. If the unsimplified Boolean expression is more extensive than one expression to the left of the equal sign or copula, then the FULL STOP key must be pressed. This key causes the machine to simplify the portion of the expression already entered and it also permits the input of additional symbols. Once the entire left-hand portion of the expression is entered, then the copula or equal key is depressed. This action enables the user to enter the right-hand portion of the expression. Once this operation is completed, the FULL STOP key is depressed once more and the machine will reveal the simplified Boolean expression in the logic windows at the front and rear of the machine. The machine is reset by pressing the FINIS key. Jevons (1870) states that pressing the FINIS key, "reduces the whole of the rods [wooden bars] to the neutral position, and renders the machine, as it were, a *tabula rasa,* upon which an entirely new set of conditions may be impressed independently of previous ones" (p. 513). It is not possible to enter an erroneous expression even if the user does not understand the significance of the keys, since pressing the wrong letter key would not result in the lever engaging any pins, thus the machine would not change state.

While Jevons refers to his device as a logical machine, what he actually created was a simple digital computer, perhaps the first successful one of its kind. In addition to input and output devices, the keyboard and the logic windows respectively, the machine also contained a central processor, the levers and the pins, as well as a memory, the position of the wooden bars. The machine operates in two states, either a pin is engaged and the bar is moved a set distance, or this action does not occur. This method of operation differs significantly from analogue machines, such as Babbage's gear-driven devices, where gears are moved by varying increments, and different parts of the devices move at different rates.

Jevons did not design his logical machine as a calculator or as a computer. Jevons (1877) states, "these mechanical devices [the logical abacus and the logical machine] are not likely to possess much practical utility. We do not require in common life to be constantly solving complex logical questions... the machine and abacus have nevertheless two important uses" (p. 112). While one use was the propagation of Boolean logic over the then common Aristotelian logic, the other important use is of greater concern to this work. Jevons (1877) states,

> I believe that these mechanical devices, or something of the same kind, will then become useful for exhibiting to a class of students a clear and visible analysis of logical problems of any degree of complexity, the nature of each step being rendered plain to the eyes of the students. I often used the machine or abacus for this purpose in my class lectures...." (p. 112)

It is clear from his account, that Jevons used his logical machine as a teaching aid. The provision of two logic windows facilitated its use in this way. Placed on a desk, for example, the instructor could press each key and observe the result in the front logic window, while the class could observe the result in the logic window at the rear of the machine. The device could have been used as a teaching machine, a function that Jevons seems to have been aware of, but did not employ. Like several subsequent educators who will be discussed in later chapters, Jevons notes that before anyone can use the machine successfully, he/she must know the lay of the keys as well as the meaning of the Boolean symbols and operands. The mastery of additional skills and operations in this instance, tends to complicate learning rather than simplifying it. The use of the logical machine as a teaching machine, therefore, would likely compound the complexity of what was to be learned (Jevons, 1877).

Although there is a popular contemporary belief that digital computers and computer-assisted instruction are developments of the twentieth century (Ceruzzi, 1983; Alessi & Trollip, 1985), it is evident that Jevons was aware of such a possibility as early as the late 1860s. There is evidence of at least one other educator who designed a similar logical machine during this period.

Marquand's logical machine

Augarten (1984) notes a device made in the 1880s by Allan Marquand, a professor of logic at Princeton University. Photographs of the device reveal it to be similar to Jevons' logical machine. A simpler keyboard and the use of pointer hands rather than logic windows appear to be the major differences. It is not known if Marquand's device is based on the work of Jevons, or whether Marquand designed his device independently. It is also not clear for what Marquand used his device, but is seems likely that he did use it as a teaching aid, since its simplicity limits its usefulness as a calculator.

Although it seems that teaching machines and teaching aids for logic were in limited use by the end of this period, there is ample evidence to show that the underlying pedagogical principle of teaching abstract concepts by demonstrating them tangibly was actively employed by other educators in several other subject areas.

Apparatus for scientific demonstration

Physics appears to have been one of the first subject areas where the pedagogical practice of demonstrating abstract concepts tangibly by means of instructional devices was applied generally. Daumas (1972) claims that such a pedagogical approach for physics was developed and first used in some Dutch universities by the late 1600s. There is one notable example that suggests that this approach may have been introduced earlier.

To illustrate his concept that the pull of gravity is the same for all bodies, Galileo Galilei (1564-1642) is alleged to have dropped two cannon balls of different mass from the leaning Tower of Pisa about 1590 (Gunther, 1923a). Although this event may not have occurred, the account is an example of how teaching aids can demonstrate a concept in a tangible manner. It may be contended that Galileo was actually performing an experiment. If this were so, and if he was not sure of the outcome, then it is unlikely that he would have performed the experiment in a public place in front of many individuals. As we have seen in Cicero's explanation of the solar system (see Chapter II) a tangible demonstration of an abstract concept does not always mean that the concept is valid simply because it can be demonstrated tangibly. The pedagogical principle of demonstrating abstract concepts in tangible ways did gain favour in universities, nevertheless.

Not all of the apparatus used for demonstrating scientific phenomena and concepts can be considered teaching aids. Some devices such as microscopes, other optical instruments and air pumps fall into the category *necessary tools*, since these devices are required to create particular conditions. Other apparatus, however, is designed solely for demonstration purposes. Examples include weight and string devices used to demonstrate concepts of the mechanics of physics (Daumas, 1972).

By the beginning of the eighteenth century, the method of teaching physics by demonstrations and experiments had spread to most European universities (Daumas, 1972). Why was there so much apparent interest in using a pedagogical method that differed radically from traditional methods? It seems that changing social factors were largely responsible for this. Conservative forces such as the Inquisition attempted to restrict the propagation of Galileo's ideas and methods as well as the ideas and methods of other innovators. The influence of such interest groups diminished in most of Europe by the late seventeenth century (Gunther, 1923a). One of the major factors for the increasing use of teaching aids in science was its apparent popularization. Segments of society that had hitherto been largely ignorant of science began to show interest in it (Daumas, 1972). Daumas (1972) also notes that the new devotees of science tended to be, "an audience unaccustomed to abstract thought" (p. 137). Given that the popular audience did not possess the background necessary to understand lectures on the concepts of physics, for example, it follows that a pedagogical approach using teaching aids to demonstrate those concepts in tangible ways would satisfy the need of these learners. Daumas (1972) states, "Apparatus to demonstrate these phenomena [the concepts of science] was an effective and useful auxiliary in efforts to popularize scientific knowledge, and the fashion for machines went hand in hand with the work of the popularizers" (p. 137).

The popularization of science for individuals who were not used to abstract concepts was not the only use of scientific teaching aids. By the mid 1700s, teaching science through demonstration and experiments gradually gained favour as the preferred pedagogical method among professors at universities in Europe and the United States (Bedini, 1964; Daumas, 1972). The diversity and the availability of teaching aids for science increased by the mid 1800s. Notable scientists such as James Clerk Maxwell continued to design their own teaching aids, and these aids were used as integral and indispensable parts of their methods of instruction (Gunther, 1937).

Summary

We have seen how the consideration of pedagogical method, or the development of pedagogical method from theory during this period, led both to the increased invention of instructional devices and to their increased use. It may be asked why teaching machines were not more prevalent during this period, given the increased interest in and use of teaching aids. From discussions provided in this chapter, it is apparent that although new pedagogical methods were devised and employed, the role of the teacher as the main provider of information remained unchanged. Maria Montessori is one example of an exception, but it is likely that her limited knowledge of available technology and her ignorance of previous developments with teaching machines prevented her from devising such apparatus. It is also important to keep in mind that one of the major criticisms of her method is that she insists that much of what the child learns is from the didactic apparatus, not the teacher (Morgan, 1913).

We have also seen how most teaching aids during this period were produced by the individual who invented them or by a small number of commercial firms. Daumas (1972) notes that the demand for teaching aids increased to such an extent during the late 1700s and throughout the 1800s, that many commercial firms began to produce them. Apart from meeting the demand for the products, these firms were interested in securing a profit. In addition to gaining a competitive edge some firms either invented their own instructional devices, or they adapted devices designed for other purposes so that they could be used as instructional apparatus. The impact of commercial factors on the design and the use of instructional devices will be considered in a subsequent chapter.

Chapter V

Development of teaching aids from 1900

Most of the teaching aids discussed to this point, with the exception of a few described by Erasmus and by Locke, were designed primarily to assist instruction. Other teaching aids, such as some of Montessori's apparatus, were also designed to function as toys or objects of amusement. It also appears that most of the teaching aids produced by the end of the nineteenth century were devised from the basis of some theory of learning (see Chapters III and IV). The popularity of the so-called *object method* of teaching is evident by the large number of individuals who designed and used teaching aids in different formalized educational settings. This apparent popularity indicates that their use was accepted by many educators by the beginning of the twentieth century (Judd, 1918). The importance placed upon teaching aids by some school boards translated into significant expenditure. In 1912, for example, the Edmonton Public School District Number 7, in the Province of Alberta, spent $17,317.32 for general "Apparatus and Equipment". While this amount does include the costs of some necessary tools such as blackboard chalk, the figure does not include the costs of science apparatus and "Physical Culture Equipment", nor does it include the amounts spent on furniture, buildings and art supplies. At the same time, the total spent for library books was $5,398.06 (*Henderson Directories Alberta Ltd.*, 1913, p. 133). It is clear from these figures that using instructional devices was considered important in this school district early in this century, and that a significant proportion of the budget was allocated for the acquisition of such apparatus.

Some educators go so far as to claim that teaching aids had become indispensable adjuncts for teachers by this time. For example, Bennett (1925) states, "there is little economy in paying teachers salaries and denying them the apparatus necessary to make their work effective as there is in employing any other class of workers and denying them the requisite tools" (p. 62). In spite of the sustained interest in instructional devices exhibited by many educators, this chapter will show how some theories of learning are ambiguous so that particular instructional devices may be deployed by instructors in ways that hinder rather than aid instruction.

While the trend of developing and using teaching aids continues at present, in part sanctioned by educators and educational theorists, there are other individuals and agencies who devise apparatus for other purposes, and who later claim that their apparatus is appropriate for instructional purposes as well (Soles, 1963). In some instances, the apparatus is marketed as a toy that may also help to teach or educate the user, while other apparatus is designed for completely different purposes and is only later adapted for use as an instructional device. This chapter will describe the changes that have occurred in the development and the theoretical bases of teaching aids during this period. The possible influence of teaching aids and theories of learning on the development of a discrete effort to produce teaching machines will be examined and discussed in this chapter as well.

Examples designed for educational purposes primarily

Quinn's teaching aid for piano chords

At least one individual devised apparatus to assist students in learning the layout of piano keys and particular chords. One such device was patented in 1905 by Marcus Quinn of Chicago, Illinois (United States Patent Number 788,063, April 25, 1905). The device consists of a triangular piece of wood which is placed on a piano directly above the keyboard. This triangle acts as a holder for a strip of celluloid printed with a number of different black and white bars, coloured bars and index marks. The bars indicate the keys that make up the various chords. With the aid of the index marks, the user is able to place the celluloid strip onto the holder so that the centre of the strip is aligned with the centre key of the piano. If this operation is done correctly, the coloured bars should be aligned with the appropriate keys comprising the 14 particular chords that they represent. Quinn notes that there may be some misalignment depending upon the size of the keyboard. Assuming that the guide is placed correctly, and that the user is already familiar with the correct placement of the hands on the keyboard, then it is possible for the user to play the various chords illustrated on the celluloid strip. Other index marks enable the user to shift the celluloid strip either up or down on the keyboard. This action permits the user to play transposed chords. Quinn states that by using this device, "a person having no knowledge of music or of musical notation can quickly and easily learn the chief and most useful chords of all keys by means of a simple non-technical system of notation" (United States Patent Number 788,063, April 25, 1905).

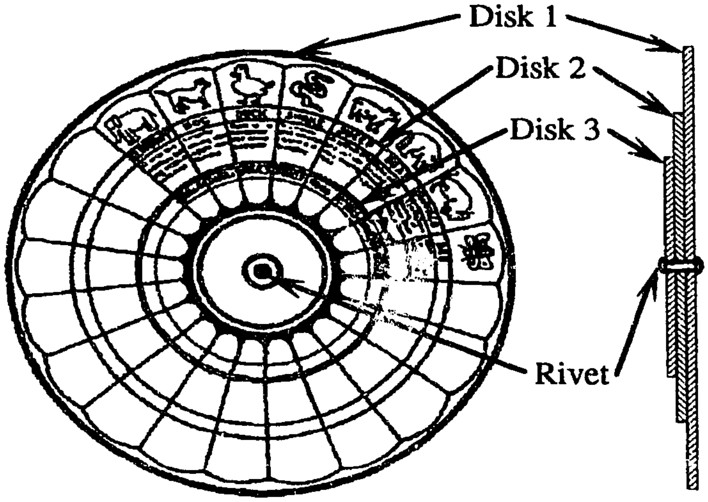
It is evident that Quinn's apparatus is intended solely for instructional purposes. While Quinn may contend that his device can be used without the assistance of a teacher, in the manner of a teaching machine, the extreme simplicity of the device permits a naïve user to possibly make serious mistakes. Such a user may place the celluloid strip incorrectly, thereby playing notes that do not comprise the proper chords. If such errors are not corrected within a short time, then it is likely that when they are discovered, the user will have to *unlearn* the false chords. A similar problem exists if the user does not know proper hand techniques. It is possible that the user will develop poor playing techniques. To be effective, therefore, Quinn's device must be used in conjunction with a music teacher, or the device should be used by individuals who already know correct hand placement and the rudiments of the keyboard.

It seems as if Quinn designed his teaching aid from the basis of a notion of learning, namely that chords are fixed positions of the hands striking particular keys simultaneously, so if one is shown the correct keys to strike, then it should follow that the individual will learn the chord and will also learn to transpose the chord as well. A fault with this notion of learning is that it does not contend with other possible outcomes of this method of pedagogy, considering especially those users who might not possess the level of knowledge that Quinn assumes is already present. It appears as if Quinn was not an educator, or at least was not an educator who was familiar both with learning theories and their outcomes when applied practically.

The apparent simplicity of Quinn's device belies serious pedagogical flaws that can result in his teaching aid doing more harm than good. To be sure, there are many other teaching aids that possess similar flaws. Dobbs (1930) notes that many flawed teaching aids occur as the result of not considering theories of learning or practical pedagogical problems. She notes that many educators are misled frequently by claims of manufacturers about the efficacy of their apparatus or by the initial interest shown in the devices by students. Dobbs (1930) states, "it seems to be so easy to mistake superficial appearances for real accomplishment, and so hard to appreciate the subtle evidences of genuine growth or discover the factors it involves" (p. 80). Although Dobbs (1930) notes some of the problems with teaching aids designed by enterprises not familiar with educational theories and practices, teaching aids continue to be devised and marketed by such enterprises.

Hamilton's pictorial apparatus

Many teaching aids devised in this century are based on the theory of learning followed by various educators in the last 300 years (see Chapter IV) that learning is facilitated by proceeding from the concrete to the abstract. While many of the teaching aids from that period possess enactive attributes such as the movement of beads to show particular arithmetical functions, many of the teaching aids developed in the twentieth century omit the enactive stage and begin with the presentation of symbols and progress to their association with abstract concepts. One example is the apparatus patented by Albert Hamilton of Newark, New Jersey, in 1924 (United States Patent Number 1,516,097, November 18, 1924). The device consists of three concentric cardboard disks printed with information that are held in position by a rivet driven through their centres. All three disks have a number of lines segments printed on them. The segments are drawn so that they may be aligned on all three disks. Each segment on the largest diameter disk contains an illustration of an animal. The segments on the next largest disk contain names and descriptions. The segments of the smallest disk contain words describing the sounds that the animals make. Figure 44 (after United States Patent Number 1,516,097, November 18, 1924) depicts the front and cross-sectional views of Hamilton's disk-type teaching aid. Only some of the segments are complete in this drawing.



Front view Cross-sectional view

Figure 44. Hamilton's concentric disks teaching aid

To use the apparatus, an individual rotates the disks to align the correct name, description and sound with a particular animal. In most instances, the information aligned with the illustrations of the other animals will be incorrect. Hamilton claims that this condition of the apparatus is also instructive

> by permitting them [the users] to associate distinctly unrelated subject matter with objects or vice versa, thereby causing merriment in a logically minded child, to whom obviously ridiculous or misplaced statements associated with non-related pictures or objects will cause much interest and entertainment. (United States Patent Number 1,516,097, November 18, 1924)

Although entertainment may be a means to hold the attention of the user, several assumptions are made about the learner, some of which may not always be valid. First, it is assumed that the user knows how to read. Second, if the user does know how to read, it is further assumed that the individual is also familiar with the particular words that approximate the sounds that the animals make. Third, it is assumed that the user already recognizes the appearance of least some of the animals represented. While the device cannot be used properly if the individual does not know how to read, if the user is unfamiliar with some or all of the animals, and if the device is used without the supervision of someone knowledgeable, then it is possible for the user to associate incorrect information with particular illustrations. In such cases, instead of assisting learning, Hamilton's device will hinder the process. It does not appear that Hamilton considered these factors when he created his device, since he claims that a user who does not know the attributes or sounds of a particular animal is encouraged, "to use its [the user's] logic and reason in applying such abstract data [the descriptions and sounds] to the subject or object" (United States Patent Number 1,516,097, November 18, 1924).

It is important to note that some contemporary teaching aids and devices sold as toys follow the same principle as Hamilton's apparatus. Most of these contemporary devices, however, either link the illustrations to the corresponding information, or the apparatus functions as a teaching machine and provides instructional feedback.

Juhász's teaching aid for arithmetic

As in earlier periods, most teaching aids designed in this century, primarily for use with formalized instruction, assist with instruction of basic arithmetic functions. Several such teaching aids embody some of the principles of learning by interacting with the apparatus advocated by Montessori (1912) and later by Bruner (1964). While these teaching aids require the student to interact with them enactively, most of the devices are to be used with guidance from the teacher, rather than having the student *discover*, through trial-and-error techniques, the principle or concept being presented. An example of a teaching aid that demonstrates concepts concretely, but which requires the supervision of a teacher or instructor, is the apparatus patented by Josef Juhász of Szemlak, Austria-Hungary in 1907. Juhász's teaching aid is intended for arithmetic and it consists of a wooden or cardboard base plate fitted with a number of partition strips on both the front and back surfaces. The placement of the strips form guideways for specially printed cards. The shape of the partition strips also permit only particular portions of the printed cards to be visible. The entire assembly is held in a wooden frame (United States Patent Number 856,068, June 4, 1907). Figure 45 (after United States Patent Number 856,068, June 4, 1907) shows the appearance of a portion of one side of Juhász's teaching aid for arithmetic.

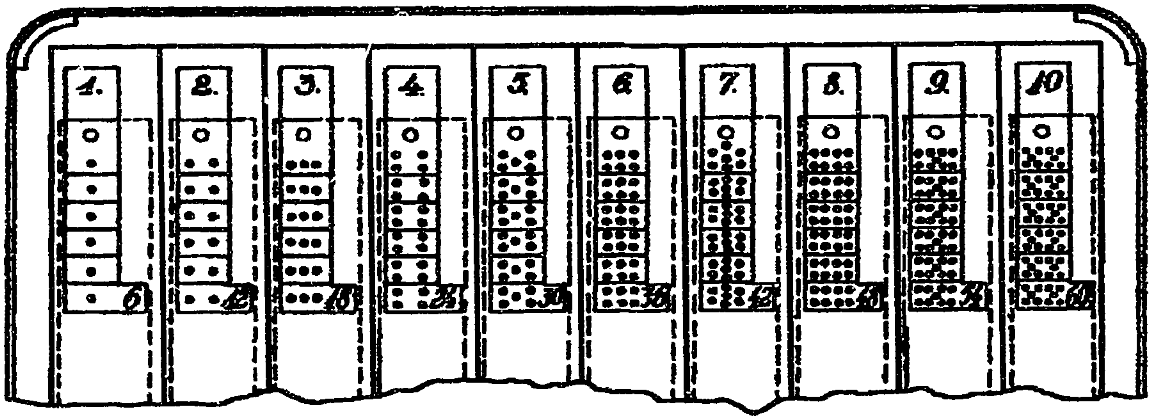


Figure 45. Juhász's teaching aid for arithmetic

The cards are printed with combinations of dots as well as particular numbers. The device, as arranged in Figure 45, is intended to illustrate the principles of multiplication. Other cards may be inserted to demonstrate addition or subtraction. The arrangement of partition strips on the opposite side of the apparatus facilitate the demonstration of division.

Juhász intends that each student in a class will be supplied with his apparatus, thus permitting the students to proceed individually at different rates. Although it may seem that Juhász is advocating individualized instruction, he does not provide an explanation why a teacher should want to use his apparatus for such a purpose. Convincing teachers to use his device seems to have been a concern and a possible problem, since Juhász notes that his device is also useful for calculating and for illustrating particular arithmetical operations (United States Patent Number 856,068, June 4, 1907).

While it does not appear that Juhász's device attained widespread use or commercial success, other contemporaries designed instructional apparatus both from a basis of learning theory as well as from the perspective of common perceived needs in particular pedagogical environments, with much greater success. One such individual was M. E. LaZerte.

LaZerte's analysis of learning and pedagogy

Milton Ezra LaZerte (1885-1975) spent most of his career in education in the Province of Alberta. He began in 1910 as a teacher in a one-room rural school which contained most of the grades from one through nine, and he eventually became the first Dean of the Faculty of Education at the University of Alberta in Edmonton (Chalmers, 1978). LaZerte was primarily a teacher of arithmetic and mathematics, so most of his efforts were concentrated on improving the efficacy of instruction in these subject areas. LaZerte (1922) contends that many of the problems with teaching in ungraded classrooms can be alleviated in part through the use of instructional materials that may be used by individual students without constant guidance from the teacher; individualized instruction (p. 30).

LaZerte conducted a series of experiments using several classes of elementary school pupils in Alberta during the early 1920s. Considering mathematics in general and problem solving specifically, LaZerte (1927) notes that students make many different types of errors, not simply errors in performing particular mathematical operations. LaZerte (1927) identifies 35 discrete errors that students may make that will result in wrong answers. The errors include difficulties in reading or understanding the language (English) the inability to apply principles or relationships to problems, difficulty in discerning the logical sequence of the problem or question, and a lack of understanding the meaning of key technical terms (p. 44).

On the basis of his experimental data, LaZerte (1927) concludes that the efficacy of instruction is likely to be improved if mathematics is related to practical examples or to objects in the environment familiar to the students. These findings corroborate his earlier anecdotal observations. LaZerte (1922) states,

> Before the child has experienced the need for a number, before he has used it, talked it and lived a little of it, we introduce him to a set of number symbols. A deadening process begins at once. Instead of thinking number the child tries to think in symbols; THREE now ceases to be a number idea and becomes that peculiar twisted mark, 3. (p. 30)

Instead of forcing a student to contend both with theory and symbols simultaneously, LaZerte maintains that instruction should consist first of the student interacting with actual objects. Concepts of how the objects can be related can then be introduced as well as symbolic representations of the objects. In this respect, LaZerte's conclusions about the problems encountered in learning mathematics are similar to those of Quintilian, Rousseau (1948) and Bruner (1964) (see also Chapter IV). Unlike many earlier theorists and practitioners, LaZerte endeavored to base his conclusions on quantifiable data from scientific experiments rather than from unstructured observation. LaZerte (1927) states that systematic observation and research, "form the only sound basis for educational procedure" (p. 11).

As we have seen in the past with individuals such as Quintilian, Erasmus, Locke and Montessori, teaching aids provide convenient vehicles for demonstrating abstract concepts concretely. LaZerte evidently did arrive at similar conclusions about learning, since he also concurs that abstract concepts may be better understood if they are first related to concrete representations. LaZerte, Dey and Svidal (1959) state, "Eliciting the facts in a problem involves a move from the concrete to the abstract... Children may be helped to make this transition by the use of concrete situations devised to represent abstract ideas" (p. vii). LaZerte, Dey and Svidal (1959) describe a six-step hierarchy to illustrate the distinction and the transitions from concrete to abstract,

> 1. Real objects: apples, desks, scissors, etc. 2. Stylized objects: beads, rulers, blocks. 3. Representations of real objects; that is, pictures of apples, desks, scissors. 4. Representations of real objects; that is, pictures of beads, rulers, blocks. 5. Representational symbols such as dots, circles, crosses, lines, etc. 6. Arithmetical symbols: six, four, plus, minus, etc. (p. vii)

The authors indicate that it is not necessary to use all of the steps in teaching every lesson, and that there is also no rigid timeframe for proceeding through the sequence. LaZerte, Dey and Svidal (1959) also note that the transition from concrete to abstract may be accelerated by having the students interact with the objects in each category.

LaZerte (1922) notes that appropriate teaching aids were rare in most schools during the first quarter of the twentieth century. LaZerte (1922) states, "there is little apparatus in our schools to assist the teacher in giving a practical setting to the work that covers the field from group counting in primary years to the development of the angle-sum theorem in grade VIII geometry" (p. 30). One might conclude from this remark that there was little if any instructional apparatus available to teachers at that time. This was not the case, however. As we have seen in the previous chapter, many individuals and enterprises both produced and marketed teaching aids during the nineteenth century. This process continues in the twentieth century. The *A.T.A. Magazine* of June 1920, for example, contains an advertisement of the George M. Hendry Company of Toronto, listing several word building frames and drill cards (pp. 17-18). LaZerte's (1922) criticism about the availability of teaching aids was not erroneous, since most of the teaching aids available at that time were not enactive, but were symbolic. There are notable exceptions, such as mechanical planetaria, globes, capacity measures, and bead frames (George M. Hendry Co. advertisement in *A.T.A. Magazine*, November 1920; George M. Hendry Co. advertisement in *A.T.A. Magazine*, December 1920, p. 19). A factor that can hinder the deployment of commercially-produced devices is cost. In 1920, for example, bead frames ranged in price from $1.00 for a small hand-held model, to $12.50 for a large version suitable for classroom use (George M. Hendry Co. advertisement in *A.T.A. Magazine*, December 1920, p. 19).

Cost is noted by LaZerte (1927) as being a major hindrance to the deployment of enactive teaching aids. He considered the influence of the business world on the functioning of public schools to be a greater hindrance to pedagogical development rather than cost. LaZerte (1922) states, "The business world demands a showy facility in computation and cares less for the trained thinker who could in a couple of months acquire the necessary speed in mechanical work. The schools continue to supply the demand and so the child is aviated over his early mathematics" (p. 30). To address these problems, LaZerte himself devised several instructional devices, and he also provided textual and resource material with them to guide educators on how to use them both appropriately and effectively. While most of LaZerte's instructional apparatus can be considered to be

LaZerte's teaching machines will be described and discussed in the next chapter.

LaZerte did not come upon the idea of using instructional material independently. By the mid 1920s, he was working towards his doctorate under the supervision of Charles H. Judd of the University of Chicago. Judd and some of his colleagues used teaching aids in their educational research, and also advocated the use of teaching aids by classroom teachers (LaZerte, 1927, p. 11). It is important to note that Judd, like Locke, did not promote the use of devices marketed by commercial enterprises. Instead, Judd preferred instructional apparatus to be constructed by the students themselves (LaZerte, 1927). This view was adopted by LaZerte as well. Another influential learning theorist of the time who advocated the use of instructional devices, was Edward Lee Thorndike (1874-1949). While Thorndike likely did not communicate with LaZerte directly, many of Thorndike's publications were readily available and LaZerte makes frequent reference both to Thorndike's scientific method of analysis as well as to some of his theories of learning.

Thorndike's theories of learning and pedagogy

As early as 1906, Thorndike contends that the teaching of concepts can be improved and facilitated by relating them to relevant concrete objects that are likely to be familiar to most students. Thorndike (1906) states, "Fractions become easy with the help of apples and blocks and knives and jig-saw because the instinctive tendencies to attend to concrete objects and to enjoy physical action and manipulation are called into service" (p. 22). His views of pedagogy, at this point, are similar to the views of several earlier educators already noted, such as Montessori and Locke.

Although Thorndike may well be a learning theorist who has had a great influence on many North American educators of the twentieth century, some of his writing can be both misunderstood and misrepresented. For example, Thorndike (1931) contends that most organisms, in this context meaning most animals including human beings, learn in the same general manner (p. 163). Someone reading this passage without considering the clarification that Thorndike provides elsewhere, may conclude that his description of animal learning also encompasses the entirety of learning in human beings. This conclusion has been made by some modern educators (Hergenhahn, 1988).

The fundamental basis of Thorndike's theories of learning is referred to as *connectionism*. Connectionism entails a supposed neurological connection between stimuli in the environment attended to by an organism, and particular responses. Some of the responses to stimuli and their neurological connections, therefore, are contended to be inborn or reflexive; they are indigenous to the organism and may or may not be modifiable (Thorndike, 1913a). Thorndike (1913b) states that a human being, "never acts like a *tabula rasa* on which external situations write each its entire contribution..." (p. 35). This point is important to note, since he advocates an object method of teaching that is similar in principle to that described by Locke, while Thorndike's theoretical explanation of human learning is radically different.

Aside from reflexes, Thorndike (1913b) distinguishes four additional varieties of learning in human beings: 1) simple connection-forming; 2) connection-forming involving ideas; 3) analysis or abstraction and 4) selective thinking or reasoning (p. 17). Elaboration of these varieties is not cogent to this work beyond the clarification that Thorndike himself makes, that learning in human beings, while similar in principle to other animals, is more complex. Thorndike (1931) states that in addition to *animal-type* learning, "man adds the ability to acquire an enormous fund of ideas, the ability to review in thought what has happened and plan for what may happen, to analyze and conceive and infer" (p. 167).

Thorndike contended initially that learning in general was mediated primarily by factors he calls *laws*. Thorndike does not define these factors consistently, nor is he likely to cause confusion among some educators. One of the most important of Thorndike's early *laws of learning* is called the *law of exercise*. It appears that Thorndike's (1912) initial definition is, "other things being equal, exercise strengthens the bond [neurological connection] between situation [stimulus] and response" (p. 95). Further to this law, Thorndike (1912) also states that, "by repeatedly inducing a child to respond to the question, 'How many are four and two?', by saying, 'Six,' a bond is formed between that situation and that response" (p. 95). A logical conclusion from this statement is that drill and instructional devices that present drill exercises are effective methods of improving learning and performance. Yet this quote is at variance both with previous and subsequent statements Thorndike makes in regard to the efficacy of drill.

Thorndike (1906) summarizes a study undertaken between 1895 and 1900 by O. P. Cornman, who used several control and experimental groups of school children (pp. 268-273). The study was designed to ascertain whether or not drill exercises actually aid students in learning to spell. Cornman's study indicates that classes that were taught spelling without the use of drill, the experimental groups, showed little difference on spelling tests between classes that did receive drill exercises, the control groups. Cornman concludes that drill does not appear to improve students' ability to spell. In consequence, he advocates that such techniques and, therefore, devices that aid in the presentation of drill, should be dispensed with (cited in Thorndike, 1906, p. 273). In spite of summarizing Cornman's study and findings, Thorndike does not present any discussion or opinion about their validity or relevance to his theories of learning. While Thorndike (1912) seems to advocate drill, subsequent works present contradictory advice. Thorndike (1913b) expands upon the law of exercise, dividing it further into two subsidiary laws, the *law of use* and the *law of disuse* (pp. 2-5). One possible misunderstanding of the use of his law of exercise is addressed. Thorndike (1913b) comments that a common interpretation of the law of exercise is that it is, "supposed to be that 'practice makes perfect,'... But practice without zeal—with equal comfort at success and failure—does *not* make perfect..." (p. 22). Another law of learning is supposed to be applied simultaneously. That law is the *law of effect*, which refers to the consequences of the response to the stimulus. Stated simply, a consequence that is considered *satisfying* to the organism tends to strengthen the associated connection, while a consequence that is considered *annoying* to the organism tends to weaken the associated connection (Thorndike, 1913a). In respect to drill, Thorndike (1913b) notes that unless it is ascertained that the activity is satisfying to the student, "unproductive or extremely wasteful forms of drill are encouraged" (p. 22).

Thorndike does not appear to indicate what specific drills are beneficial or detrimental to students, or for how long a student should exercise a given bond. Thorndike (1913b) for example, states, "so there is, in whittling, penmanship, typewriting, drawing, spelling, purity of diction, and the like, for any given person a point beyond which practice brings rapidly diminishing returns for the world's good. Many functions are practiced far too long by many pupils" (p. 184). To be sure, Thorndike (1913b) summarizes a variety of experiments he and others have undertaken to ascertain precisely how much repetition of a bond is most effective, but no definite guidelines are provided. It is also important to note that most of the studies either undertaken or cited by Thorndike, measure variation in the speed of motor skills such as typing, writing numbers and speed in telegraphy. Thorndike does not seem to have made a distinction between learning and performance that subsequent theorists such as Edward Tolman and others have been able to show through experimental studies (Tolman & Honzik, 1930). In spite of the observations of earlier educators such as Quintilian and the more recent experimental findings by Cornman (cited in Thorndike, 1906) Thorndike persisted in his assertion that drill or the exercising of a connection improves learning. By 1930, however, Thorndike withdrew his law of exercise because his later experiments, as well as the findings of others, indicate that drill does little to improve learning. Thorndike (1931) states, "The repetition of the wire. In and of itself, it may teach him as little as the message teaches the switchboard" (p. 14).

A probable misfortune of Thorndike's varying position on the rôle of drill is that some educators and manufacturers of instructional devices conclude that their use of drill and drill apparatus is based on sound educational theory. This phenomenon is probably not restricted only to those educators who took the time to learn Thorndike's theories. Thorndike wrote several school textbooks on arithmetic, and their use was widespread. In one such textbook, a revised edition used in schools in the Province of Alberta, Thorndike (1917) notes that the book is improved because, "elaborate computations of interest, principal, and rate, are replaced by systematic drills to secure mastery of the computations which life requires" (p. vi). As well, there is evidence to show that some enterprises select favourable elements from Thorndike's theories, usually out of context, in an attempt to give credibility both to the appropriateness and to the efficacy of their devices (see Chapter VI). It is possible that when Thorndike concurred with the views of other educators, that drill does little to improve learning, the use of some instructional devices for drill were discontinued because they were seen by some educators as serving little or no appropriate purpose.

The previous example may suggest that theoretical analyses of learning are faulty although they appear to be supported by experimental findings. While one may make such an assumption, a better conclusion might be one that does not make such a broad generalization. From the previous discussion, it appears that it is necessary for educators and manufacturers of instructional devices to consider other factors in addition to theories of learning. LaZerte, while extolling educators to consider theories of learning, also advocates the consideration of additional factors including the appropriateness of pedagogical methods for particular educational situations.

LaZerte's primary number booklets

One of the major problems LaZerte (1953) notes about many of the rural schools in Alberta, before they were closed, was that each school usually contained several grade levels taught simultaneously by one teacher. This means that the teacher usually had limited time to provide each grade and practically no time to spend helping individuals in each grade. In most schools arranged in this manner, when a student finishes a particular assignment before expiry of the allotted time, that student either does other work, or he/she remains idle until the teacher gave new instructions. If the student has questions while doing an assignment, there might be a considerable delay before the teacher is able to respond. During this time, if the student happens to be doing an assignment incorrectly, it is possible that erroneous procedures or concepts will be learned. The longer the student works without some sort of corrective feedback, the worse the problem may become. Bearing such situations in mind, LaZerte designed a series of teaching aids that would assist students in learning the fundamentals of arithmetic while, at the same time, reducing the need for attention by the teacher without the risk of the student using or developing incorrect procedures or concepts. The teaching aids, a series of workbooks designed for use with grades one to three, are called *primary number booklets.* Each booklet consists of pages that have a number of rectangular openings cut into them. Above each opening is some sort of equation or simple operation. It is assumed that before students use these booklets, they are first taught the appropriate arithmetical operations by the teacher (LaZerte, 1937).

In use, the student places a sheet of ordinary paper behind one of the right-hand pages of the booklet. The student then reads the questions above each rectangular opening and writes the answer on the paper exposed in the openings. Once the page is completed, the student removes the sheet of paper, places it on the left-hand side of the booklet and then turns the page back onto the completed sheet. By doing this, the answers printed above

(LaZerte, 1937). Figure 46 (after illustration in LaZerte, 1937, p. 14) depicts the appearance of LaZerte's primary number booklet in use.

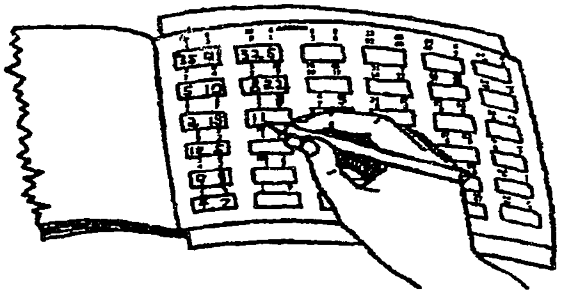


Figure 46. LaZerte's primary number booklet

By using the booklet in this way, a student is able to gain facility in performing particular arithmetical functions while simultaneously being able to ascertain whether or not his/her responses are correct. If a student finds that several errors have been made, and the error of calculation cannot be discovered, then the teacher may be summoned.

Unlike some contemporary teaching aids that LaZerte criticized because of their cost, the primary number booklets were inexpensive, selling for either 25¢ or 30¢ in 1937 and 1938, depending upon which grade level was required. It seems likely, given the budgets of small ungraded schools at that time, that most one-room schools with a grade one to grade three enrollment of approximately 10 pupils, could be equipped with primary number booklets without exhausting the budget allocated for instructional apparatus (LaZerte, 1939). Little additional expenditure is required, since students use whatever paper and writing instruments are available. Unless the booklets are defaced or otherwise damaged, they can be used repeatedly (LaZerte, 1937). It appears that the primary number booklets were successful teaching aids, since they remained in production until the 1950s, by which time most one-room and two-room ungraded schools had closed in Western Canada.

While one might conclude that LaZerte's primary number booklets are a new innovation, it should be recalled that Pestalozzi developed and used a similar type of booklet more than one hundred years earlier (see Chapter IV). Some contemporaries of LaZerte also designed teaching aids intended to facilitate individualized instruction.

Washburne's Winnetka plan

The *Winnetka plan* was devised during the 1920s by Carleton Washburne, onetime superintendent of public schools in Winnetka, Illinois (Saettler, 1968). The Winnetka plan is similar to LaZerte's primary number booklets, in that both use workbooks that contain answers to the questions asked. The materials for the Winnetka plan were marketed by the Winnetka Publishing Company (Ricker, 1938). Booklets for the Winnetka plan do not have openings cut through the pages, so it is necessary for students to write their answers either in the booklets or on a separate piece of paper in such a way that they will be able to associate a particular answer with a particular question. While this procedure may seem straight forward, the student must spend time and thought on that task as well as answering the questions in the workbook. As with LaZerte's booklets, supervision is required with the Winnetka plan to ensure that students are completing the questions properly and are not simply copying the answers. While LaZerte designed booklets only for arithmetic, the Winnetka plan includes booklets for additional subject areas tests are also included in the plan. The diagnostic tests are designed to indicate areas that are weak with each student, and also to provide suggestions to the teacher on how to ensure that appropriate remedial study will be prescribed for each student. It is contended that using this plan in as many subject areas as possible will result in a more efficient use of class time, since progress is an individual matter, not entirely dependent upon direction of the teacher; most of the students will not be idle (Ricker, 1938). Although the Winnetka plan, unlike simpler teaching aids like LaZerte's *primary number booklets*, requires considerable material and a greater modification of the teacher's classroom activity, knowledge of the plan was widespread in North America and it continued to be used in some schools well into the 1960s (Saettler, 1968).

LaZerte's activity-based programmes and teaching aids

Developing from his concern for student learning, especially within the small ungraded schools found throughout the western provinces of Canada and in some states of the United States, LaZerte designed a system of teaching aids to be the basis of an activity-based arithmetic course. Experiments to ascertain both the feasibility and the effectiveness of various instructional devices were undertaken by him beginning in the late 1920s (LaZerte, 1933). This work was interrupted by administrative duties and by constraints imposed by the Second World War. LaZerte resumed his work by the end of the war, and he conducted experimental arithmetic classes that spent 60% of available class time on individual laboratory exercises that were largely unsupervised (LaZerte, 1945). The idea of *individualized instruction* in this context does not mean that each student follows a rote program individually. Each student performs the experiments outlined, and by doing so, discovers the underlying concepts for themselves. Most of these experiments require the use of teaching aids that are designed to show an abstract concept in a concrete manner. The apparatus provided includes bead frames, various types of number boards, charts, special coloured disks, cut-out objects, and rudimentary measuring devices (LaZerte, 1945).

On the basis of his findings with experimental classes, LaZerte (1953) concludes that an activity approach to teach the rudiments of arithmetic is appropriate for general use in schools. The complete instructional package is called *Numbers tell their story,* and it consists of workbooks, manuals and teaching aids (LaZerte, 1953). The package was sold either with sets of the required aids, or with directions for fabricating them within the school. The teaching aids include: small bead frames; perception cards (domino-like flash-cards); number boards, wooden trays that can hold coloured blocks to show addition and subtraction concretely; a place value frame, a shallow cardboard or wooden box marked in thirds, with nine slots in each third intended to hold supplied coloured disks; a hundred board, a 23-inch square (1,483.87 mm^2) board marked in quadrants, with 25 hooks or nails arranged in rows in each quadrant to show sub-multiples of 100 (LaZerte, 1953).

LaZerte (1953) states that the apparatus is intended to be used by students with a minimum of teacher supervision, "if he [the student] is to profit from the course, each pupil must do all the work himself. The teacher must not teach demonstration lessons. It is assumed that all pupils will have some equipment in their hands while the class is at work" (p. ii). It seems that LaZerte (1953) advocates a method of pedagogy similar to the methods developed by Montessori (see Chapter IV) or the *discovery learning* approach defined and described later by Bruner (1961). Like Montessori before him, LaZerte soon ascertained that while his discovery method worked well in his experimental classes and with some teachers, other teachers found the method too unstructured, with the result that there was chaos in the classroom (LaZerte, Dey & Svidal, 1959). This problem is not caused by the teaching aids themselves, but by how they are deployed in the classroom. Other discovery methods, including the one devised by Bruner (1961) have also been criticized because their unstructured nature may result in chaos in some classes. This particular problem is addressed by Corno and Snow (1986) who advocate a range of *teacher mediation* to account for differences between classes and to contend with individual student differences. By providing some guidance, within defined limits, a teacher can avoid either constraining the class so that no discovery learning takes place, or allowing such an unstructured environment that chaos results.

It seems that LaZerte arrived at a conclusion similar to that of Corno and Snow, sometime after the release of the first version of *Numbers tell their story*, since a subsequent edition provides suggestions for teacher guidance. Teaching aids remain integral components of the revised method, but teachers are encouraged to provide oral instruction first and also to provide directions for group exercises with the apparatus (LaZerte, Dey & Svidal, 1959). In this revised format, the package continued to be sold into the late 1960s (royalty statements in the LaZerte Papers, University of Alberta Archives).

While it appears that LaZerte's modified activity-based method of instruction was successful, it and similar methods were superseded partially by the demise of the ungraded school and also by other teaching aids. Some of these devices were designed initially for purposes other than education.

Commercial devices adapted for educational purposes

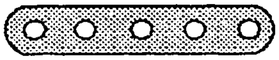
It has been mentioned in previous chapters that toys have been adapted to function as teaching aids. Quintilian, Locke and Montessori are some early educators who developed teaching aids in this manner (see Chapters II, III and IV). While educators in the twentieth century continue this tradition, there are many commercial enterprises that attempt to do the same thing, usually without a practical pedagogical basis or without much consideration of legitimate educational theory. Although toys comprise a large proportion of such devices, there are examples of objects of amusement that individuals have attempted to market as teaching aids and as teaching machines.

Hornby's Meccano

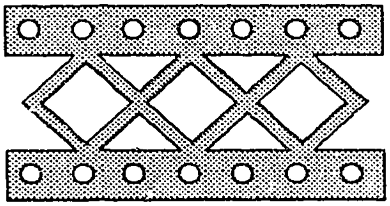
One of the earliest examples from the twentieth century is a structural system invented by Frank Hornby (1863-1936). Hornby, who is also known for his design and manufacture of toy trains, patented a miniature mechanical construction kit in 1901 (Gould, 1915). Initially, the apparatus was marketed as *Mechanics made easy*, but it is more widely known now as *Meccano*. The kits are intended to be used by children, primarily boys initially, to provide amusement and education. With the components, one may fabricate various structures, and may also experiment by building structures and apparatus of their own design.

The major components of Meccano are sheet metal strips that are stamped into various standard shapes and lengths. The strips are also punched with a number of evenly-spaced holes or elliptical openings of small diameter. The completed pieces are then painted. Small threaded fasteners and angle brackets are provided to enable the strips to be connected together. Figure 47 depicts the appearance of two varieties of Meccano strips. The objects are approximately one-half their actual size. Some kits also include lengths of metal rod and fasteners to connect them together, as well as assorted gears and wheels. Clock-work or electric motors were also includedin some kits (Gould, 1915).

Hornby consulted a professor of engineering before marketing Meccano. Hornby's main purpose for doing this was to ascertain whether or not Meccano was congruent with contemporary principles of engineering. The professor, Dr. Hele-Shaw, not only approved the engineering aspects of Meccano, but he also stated that one is able to learn the principles of mechanics by working with the materials. Hele-Shaw went further, stating that such learning could occur *unconsciously*, that is, without the user being aware that learning was taking place (cited in Gould, 1915, pp. 70-71). It was only after the sales of Meccano became successful that Hornby pursued adapting it to be a classroom teaching



Basic strip



Girder strip

Figure 47. Examples of Meccano strips

aid (Gould, 1915). To be sure, Hornby had received many requests from various schools and institutions for special sets of Meccano with instructions for its use as a teaching aid for mechanics. Such demand lead Hornby to prepare a book for this purpose, called *The Hornby system of mechanical demonstration* (cited in Gould, 1915, pp. 116-117). Hornby claims that the major advantage of using Meccano rather than lectures to teach principles of mechanics, is that the students themselves may construct models of most mechanical concepts. Hornby believes that such *enactive* activity by individuals leads to more learning than if the individual hears a lecture or observes a demonstration by the teacher.

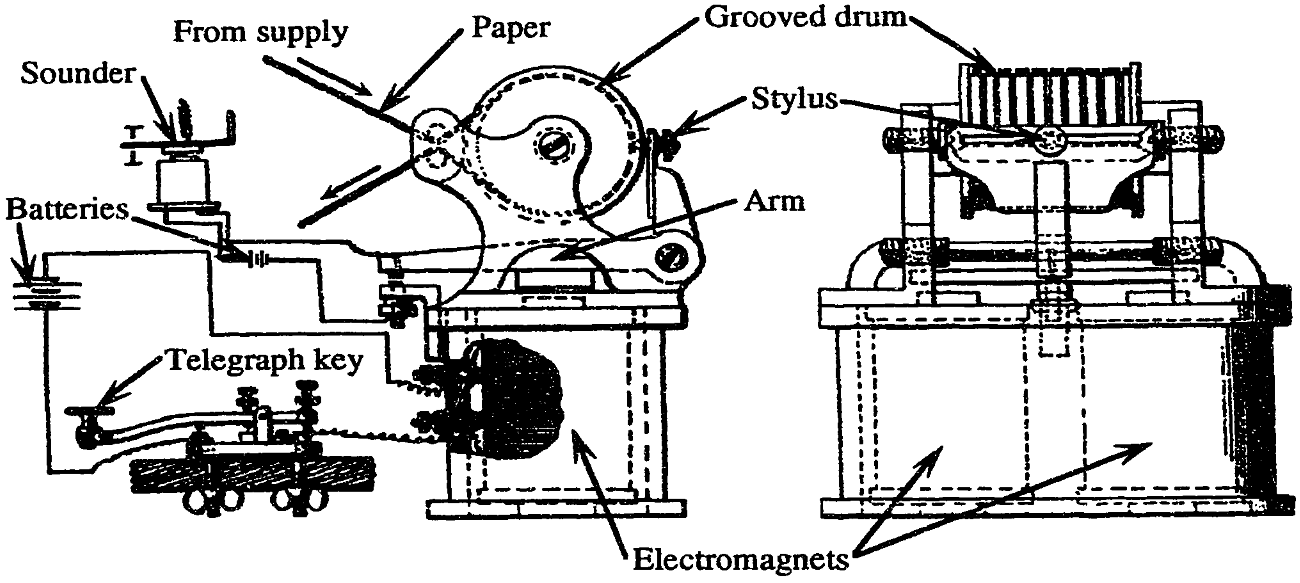
It has been mentioned in the previous chapter that the experimental method of teaching many aspects of science was well established by the end of the nineteenth century. For this reason, it is likely that Meccano was generally well received by many educators. While few studies have been conducted to ascertain whether simply playing with or using Meccano leads to learning of the principles of mechanics, Meccano and similar apparatus such as *Leggo, Tinker toy* and *Erector sets* continue to be marketed. Much of this apparatus is still to be found in many schools, although few schools appear to use the apparatus as the basis of science courses. Toys and objects of amusement are not the only commercial items that have been adapted for use as teaching aids.

Page's teaching aid for telegraphy

With the large-scale settlement of North America in the late nineteenth and early twentieth centuries, the demand for individuals possessing skill in sending and receiving telegraphic messages increased. The telegraph was the predominant means of rapid long-distance communication in that era. A knowledge of Morse code as well as a high degree of accuracy in both sending and receiving telegraphic messages were requirements for being a successful telegrapher. Paradoxically, one problem with training telegraphers was bringing students to schools with appropriate facilities. Given that many people of that period lived in rural areas, and that it was not always economically feasible for individuals to travel to larger centres where instruction in telegraphy was available, a means was devised to provide telegraphic instruction at remote locations without the need of having a teacher present.

Although correspondence schools are common in North America in the twentieth century, the nature of telegraphy makes it an unsuitable subject to be taught through correspondence. While one may learn Morse code through correspondence by being able to write dots and dashes for given letters and words, and vice versa, this method does not develop the transformation of learning into performance, for it is quite another skill to be able to translate a series of long and short clicks into words and sentences. Telegraphic apparatus is necessary for this. With these considerations in mind, Howard Page, of Fitchburg, Massachusetts, patented in 1905, a specialized modification to standard simple telegraphic apparatus, so that the equipment could be used as part of a correspondence course (United States Patent Number 789,378, May 9, 1905).

Besides a standard telegraph key and sounder, Page added a recording device consisting of a stylus that can be moved forward by the action of two electromagnets. The action of the stylus perforates a moving sheet of paper that is fed around a roller possessing several grooves along its circumference. Figure 48 (after drawings in United States Patent Number 789,378, May 9, 1905) shows the side and rear views of Page's teaching aid for telegraphy by correspondence.



Left-hand side view

Rear view

Figure 48. Page's teaching aid for telegraphy

It should be noted that the mechanisms for paper supply and retrieval are not shown. Page did not illustrate them, nor did he specify any particular mechanism. The illustration of the grooved drum in the rear view shows nine grooves. The stylus may be positioned opposite any one of the grooves and it is intended that a particular piece of paper be run through the machine nine times to minimize waste (United States Patent Number 789,378, May 9, 1905).

The device can be used in two distinct ways. First, as described previously, it may be used by a student to record particular letters, words and sentences via Morse code onto a paper roll. Once completed, the roll is sent in with the corresponding lesson, where they are corrected and returned. Second, a pre-perforated paper roll may be sent to the student who then installs it in the machine. The stylus, passing over the perforated paper causes the sounder to reproduce the perforations as dots and dashes. In this manner, the student receives practice in decoding telegraphic messages (United States Patent Number 789,378, May 9, 1905). The decoded messages may also be submitted for correction.

Pedagogical elements of remoteness and permanence

Although Page does not make specific mention of it, two major components of his apparatus are the *remoteness of the expert*, and the *permanence* of particular methods and styles. Page (1905) states, "It is well known that in telegraphy each operator has a style of hand peculiarly his own in transmitting messages, and it is essential that the student should be able to receive with equal facility all styles of transmitting..." (United States Patent Number 789,378, May 9, 1905). While it is impractical for telegraphic experts of different styles to travel to each school or student to acquaint them with different styles of transmission, Page's apparatus enables this information to be recorded and distributed widely in a form that can be reproduced with a high degree of fidelity, provided that the apparatus functions properly. It is possible, therefore, for a student in an isolated location to gain exposure at any time to any number of particular telegraphic styles, expert or otherwise.

Elements of remoteness of the expert and permanence were introduced by Quintilian with his writing practice board (see Chapter II). Although it is the student who performs the action with the letter guide, it is an expert who creates the record of his/her writing style by means of the grooved outline. The action is similar to having the actual expert guide the hand of the student, without the necessity of having the expert present. Locke's handwriting aid is a similar, though later example (see Chapter IV). The concept of bringing to the student elements of information or pedagogical styles that might not usually be available, seems to be practiced by several individuals and companies that developed apparatus for purposes other than education.

Motion pictures

While motion pictures have been available to the general public since the early 1890s, they were intended initially as entertainment. The idea of using motion pictures as teaching aids occurred to a number of individuals by the early years of the twentieth century (Saettler, 1968). This idea probably developed from the use by teachers of illustrative materials such as photographic prints and various forms of projected still images.

Thomas Edison was one of the earliest advocates of using motion pictures for instructional purposes. He controlled a commercial enterprise that manufactured motion pictures, projection apparatus as well as phonographic equipment. Edison contends that instruction primarily through the visual sense, a process sometimes referred to contemporarily as either *visual* or *iconic* learning, is superior to instruction via lecture. There are some findings that tend to support Edison's contention. Treichler (1967) claims that human beings learn 83% of information through sight alone. While Treichler does not indicate how this figure is obtained, Carpenter (1953) and Dale (1954) agree that most knowledge is learned through the visual sense. Edison's conviction of the superiority of learning through the visual sense lead him to predict, in 1913, the imminent demise of books in schools, since they would be rendered superfluous by the motion picture (cited in Saettler, 1968, p. 98). While Edison's enthusiasm may have encouraged other enterprises to manufacture motion pictures and projection apparatus for education, a number of factors impeded the widespread adoption of this teaching aid by educators.

Motion pictures do provide a permanent record and they do address the problem of remoteness of the expert or environment, in part, by enabling students to observe events, individuals, behaviors and other aspects foreign to their environment. Although such images may be vivid and not easily reproduced by other means such as still photographs or by written descriptions, the students are largely unable to interact with what is projected. To learn in such circumstances, therefore, a student must be passive and attend primarily to what is occurring in the projection. Similar student behavior is required when a class is run by a teacher, but a student can interact with a teacher, albeit at the teacher's pleasure. If a film is not interesting to the student, or if the student cannot understand what is being shown, then it is unlikely that much attention will be paid to the motion picture. A teacher may be able to modify the behavior of students, so that they at least remain quiet while the film is being shown. Interaction between a teacher and student, however, usually provides some indication as to whether or not the student is attending or whether the student does not understand what is being taught. The efficacy of instructional motion pictures has been considered by many researchers.

Pedagogical efficacy of motion pictures

Experiments to ascertain whether or not learning takes place from motion pictures have been conducted for many years. Such studies include Lacy (1919), Lashley and Watson (1922), Knowlton and Tilton (1929), Wood and Freeman (1929) and Arnspiger (1933). With the financial aid of the Fox Film Corporation (now part of the Twentieth-Century Fox Film Corporation) several experiments were undertaken by Peterson and Thurstone between 1930 and 1932 to ascertain whether childrens' attitudes could be influenced by having them watch selected motion pictures. On the basis of their experimental findings, Peterson and Thurstone (1932) conclude, "quite conclusively that the social attitudes of children are affected in a measurable way by motion picture films and that international attitudes can be guided by films" (p. 246). Peterson and Thurstone's conclusions are congruent with a later and more popular theory of observational learning proposed by Albert Bandura (1965). While many studies indicate that most students learn from motion pictures, there is no consensus as to how they should be used in the classroom.

Factors limiting the use of motion pictures as teaching aids

The poor content and organization of many motion pictures are noted as elements that contribute to the slow success of the motion picture as a teaching aid. Hankin (1931) states, "The [motion picture industry] has developed on individualist lines and there has been no central body ... to advise manufacturers on the production of educational films or to investigate the value of such educational films that have been produced" (p. 262). Aughinbaugh (1934) claims that one of the major problems with so-called educational motion pictures is that they present information in a dull manner and that they also "fail to have the continuity of the material found in textbooks" (p. 342). These observations are also shared by McClusky (1924) who claims that some instruction, place sequence for example, is more effective by means other than the motion picture. The often complex nature of motion picture projection as well as rapid changes in the technology, are additional factors that have discouraged the use of motion pictures as teaching aids.

Most early films were silent and were photographed on black and white film stock that, until the early 1950s, consisted of a base composed of cellulose nitrate, a highly inflammable and unstable material. The heat produced by some projection equipment is sufficient to cause such film to catch fire in particular circumstances (Noel, 1961). Nitrate-based films also tend to deteriorate rapidly. As these films age, they become prone to spontaneous combustion (Eastman Kodak Company, 1979). The potential danger of motion picture films prompted some American school boards, as early as 1910, to prohibit the use of motion pictures in their schools (Saettler, 1968). It is also worth noting that Edison's venture in providing motion pictures for instruction ended abruptly in 1914, as the result of two fires that destroyed most of his negative library as well as his production facilities (Saettler, 1968).

It was not until the 1940s, that the majority of educational motion pictures were manufactured in one standard width, 16 mm. Before this time, other film widths, most notably 35 mm, were common. To be able to show films of different widths, a school either had to possess several projectors, or a special, more expensive projector that could load different film widths (Noel, 1961). The protracted delay of implementing a standard film width for motion pictures intended for school use probably contributed to their slow deployment as teaching aids. This delay is noted as early as 1921 by one manufacturer who states, "to deter the purchase of a projector because of doubt is to unconsciously hamper the development of one of three factors to progress" (DeVry Corporation, 1921, p. 101). It is of interest to note that only one of these three factors refers to the education of pupils, the broadening of the child's *mental scope*. It is not stated what this term means. The other two factors are the arousal of dormant religious feelings among the public in general and the stimulation of commercial sales. It is likely that the latter factor was considered the most important by the company.

The availability of appropriate films was another factor that retarded the implementation of motion pictures as a teaching aid. It is noted previously that Edison quit supplying instructional films after conflagrations destroyed his factory and stock. Some enterprises such as the Victor Animatograph Company and the Bell and Howell Company continued to produce and to market instructional films for many years (Saettler, 1968). Other corporations, however, ended production of educational motion pictures because of poor financial returns or because of prevailing economic conditions. Fox Films, for example, discontinued their production of educational films during the Great Depression of the 1930s (Saettler, 1968). Another concern, the Atlas Motion Picture Corporation, financed by Henry Ford, ceased production during the 1920s because advertising for the Ford Motor Company, incorporated within the films, prompted some educators and parents to criticize the company's advertising strategy with a resulting drop in Ford's automobile sales (Saettler, 1968). While the Eastman Kodak company had produced a large library of instructional motion pictures during the late 1920s, the advent of motion pictures with a sound track, coupled with the effects of the Depression, resulted in that company abandoning the production of new instructional motion pictures (Saettler, 1968).

Most motion pictures were silent before 1929, with the exception of a few that employed additional apparatus. By 1930, many motion pictures were being made with a sound track on the film either as an optical image or as a magnetic strip. To be able to use such films, it is necessary to have a projector equipped for interpreting the soundtrack and amplifying the resulting sounds. The advent of sound motion pictures prompted some manufacturers to claim that this development would result in a consequent improvement in student learning, since many maintain that talking pictures are superior to the older, and usually less expensive, silent films. One advertisement of the period states, "With the meteoric rise of the talking motion picture, educators have hailed it as the SUPER-EDUCATOR of all times ... If your school is not already RCA Photophone equipped, it should be - AT ONCE" (RCA Photophone, Inc., 1930, p. 31). This technological development was probably not welcomed by many schools who had recently committed a considerable portion of their budget to purchase a silent picture projector only to find it obsolete. To overcome trepidation and reluctance to purchase projectors for sound motion pictures, some manufacturers tried to give the impression to the public that schools deprive both pupils and their parents by not using the most up-to-date apparatus. The Electrical Research Products company (1930) who distributed projectors manufactured by Western Electric, states, "Communities today have a vital interest in their instructional centers. They demand every up-to-date teacher's aid so that their schools will keep well abreast of current trends" (p. 83). In this instance, it appears that advocacy of talking motion pictures was based upon popular sentiment rather than upon effective pedagogical methods.

While there are some motion pictures designed to be used in conjunction with a synchronized phonographic record, the process is usually inferior to motion pictures with an integral soundtrack. A separate sound track process also requires additional apparatus, a phonograph and the required recording, which add to the total cost. With the addition of such an important element, sound, it may be asked how effective silent films are compared with talking pictures. Einbecker (1933) conducted a series of experiments to ascertain the relative effectiveness of sound versus silent motion pictures. The experiments were performed in junior and senior high schools. General science classes were used at the junior high school level, while physics classes were used for the experiments in senior high schools. Einbecker (1933) concludes that there is no significant advantage in using motion pictures with sound rather than using silent ones. It is apparent, however, that silent films are not appropriate for reproducing speech or for teaching subjects requiring the reproduction of sound, such as the sights and sounds of a symphony orchestra. For other activities, such as a motion picture of cell meiosis for example, sound is not essential, although it may be argued that expert narration of the process enhances what the student attends to and, therefore, learns from the film.

There is no consensus on the effect of colour in instructional materials (Durrett & Stimmel, 1982). Some educators contend that colour is not a decisive element in learning. Noel (1961) states, "Choice of black-and-white or colour is more a matter of content treatment and budget consideration than a critical issue" (p. 9). Others, however, contend that the use of colour may enhance learning. For example, Farley and Grant (1976) conclude that material can be better remembered when it is presented in colour rather than in black and white. Although the efficacy of learning from coloured films as opposed to black and white films may be debated, many motion pictures for schools are produced in colour only. Colour motion pictures are usually more expensive than those in black and white, and the additional cost may limit their use by schools. Images on colour films usually fade more rapidly than images on black and white films, so the useful life of colour films may be shorter than that of a black and white film (Eastman Kodak, 1979). The efficacy and the use of colour in instructional materials continues to be a concern with modern instructional apparatus such as computers (Alessi & Trollip, 1985).

The availability of electricity was also an important factor determining the extent of deployment of motion pictures in schools. In many areas of the United States and Canada, electricity was not available readily until after the Second World War. While battery operated projectors and small electrical generating plants were available, relatively few schools could afford them. Where practical, several school boards would purchase the required apparatus and would share it among their schools. The reliability and the safety of such equipment could be low, however (McKenzie, 1974, p. 65; Ost, 1981, p. 35).

Another aspect of motion picture technology that contributes to its limited use in schools is the skill and time required to prepare a film for projection. Most early motion picture projectors require the operator to thread the film through a path of guides and sprockets, a process that usually takes several minutes. If the procedure is not done correctly, there is a high likelihood that the film will jam or will not be projected properly. In such instances, the teacher will have to spend additional time to correct the problem. Old films, or films that have been abused or mishandled, may break during projection, requiring the expenditure of class time to repair the film so that the presentation can continue. It is likely that teachers experiencing difficulty in preparing films for projection, or those having to deal with film breaks or jams, are reluctant to use such equipment in future. This view is shared by Leverenz and Townsley (1963) who state that, "many teachers will not use films [motion pictures], tapes, slides or filmstrips if it is mechanically difficult to use them, valuable as they may be in the teaching situation" (pp. 3-4).

It appears, from the discussions in the previous paragraphs, that technological and economic considerations rather than pedagogical efficacy are the major factors limiting the deployment and the use of motion pictures in schools. While it may be argued that this view is a contemporary interpretation of past events, there is evidence from that time to support the contention that pedagogical efficacy was not the decisive factor in the deployment of motion pictures in schools. Brockway and Brockway (1939) who studied the use of sound equipment in schools, state,

> Sound pictures for educational purposes have been shunned due to costliness and lack of films with the proper educational material. The shortage of educational materials is probably due to the absence of demand, which in turn may be traced to a lack of equipment. The solution is to reduce the cost of equipment. (p. 423)

While Brockway and Brockways' (1939) analysis supports the contention that pedagogical factors are not the major consideration in the deployment of motion pictures as teaching aids in schools, it is doubtful that their proposed solution would solve the apparent lack of use.

In 1922, Charles H. Judd was appointed by the National Education Association of the United States to head a committee to ascertain the pedagogical value of motion pictures produced commercially, and to describe problems teachers and schools encounter with motion pictures and projectors (Saettler, 1968). Judd's committee found that technological problems such as film inflammability do hinder the deployment of motion pictures as teaching aids. The factor of commercialism is also cited as being potentially detrimental for the ultimate success of motion pictures as teaching aids. Judd (1923) notes that his committee, "has been literally besieged by promoters of all kinds of plans for the production of projectors and particular films" (p. 5). It was the intent of these promoters to secure approval from the committee for their particular films or apparatus. Such approval would likely convince some school boards to purchase motion pictures and projectors. In consequence of these actions, Judd (1923) recommended that his committee be replaced by another that would be charged with not endorsing any particular films or apparatus. Judd's recommendation was not accepted, and he resigned in 1923. The committee proved to be ineffective subsequently, and it was dissolved in 1927 (Saettler, 1968).

In spite of the factors limiting their use, motion pictures continue to be used as teaching aids in many schools. The use of this aid, however, is not as widespread as other aids such as the blackboard. The advent of new and specialized pedagogical approaches has prompted further promotion of motion pictures. During the individualized instruction movement of the 1950s and 1960s, for example, some manufacturers designed self-instructional materials that required the student to operate a hand-cranked film projector as part of the instructional package (Allion, 1958). As with earlier initiatives, concerns exist about the efficacy of such an approach. As well, different manufacturers persisted in marketing films in different widths, as they had done previously. While some firms produced their instructional motion pictures on 16 mm film, others used 8 mm film stock. Film-loop projectors are examples of instructional apparatus that use 8 mm motion pictures (Allion, 1958). Given the sustained lack of standardization of instructional motion pictures, it is not surprising that this teaching aid is used infrequently in most schools. It also seems that the motion picture is not gaining use within most curricula and that motion picture technology is being rendered obsolete by other media.

Recordings

While sound playback and recording apparatus were available as early as the 1880s, the technology was intended primarily for entertainment and business purposes (Chew, 1973). In a manner similar to motion pictures, a lack of standardization, expensive equipment, and difficulties in securing appropriate recordings, were factors limiting the initial use of sound reproduction apparatus in schools. A greater factor during the nineteenth century, was the technological difficulty in mass producing cylindrical recordings (Koenigsberg, 1990). By the beginning of the twentieth century, however, Thomas Edison's National Phonograph Company had developed the technology to mass-produce wax cylinders that were more robust than ones available previously. The first customer for the new moulded black wax cylinders was the International Textbook Company of Scranton, Pennsylvania (Koenigsberg, 1990). While this company did send cylinders and the necessary equipment to play them to a number of students, there is little evidence to show that many other educational concerns used cylindrical recordings. The fragility and the bulkiness of cylinders combined with the advent of disk recordings, likely contributed to the limited use of cylinders.

Unlike motion pictures, most sound reproducing equipment did not require electricity and could be operated in most environments without posing extreme safety hazards. Although some manufacturers produced cylinder and disk recordings that could be played back only with special apparatus, most recordings could be played back on most makes of machine. While changes in recording technology occurred, it was rare that such changes required the replacement of sound reproducing equipment. By 1930, for example, most recordings were made with electrical recording equipment rather than with acoustic apparatus. While the fidelity of recordings was likely improved with the new technology, copies could be played on older acoustic equipment without detriment. The factors of interchangeability, constancy, safety and simplicity of operation, were probably conducive to the use of such sound recordings in schools. As early as 1917, some educators promoted sound recordings as suitable teaching aids. Bennett (1925) states, "A good phonograph which will play the best standard records must now be regarded as an almost indispensable adjunct of a well-equipped school" (p. 70).

Besides permanence and the ability to present experts remotely, sound recordings were usually more readily available than motion pictures, since more individuals possess sound reproducing equipment than film projectors. A pedagogical element present in sound recordings, but which is lacking in motion pictures, is *random access*. Unless extraordinary procedures are undertaken, it is extremely difficult to show excerpts from a motion picture. Most sound recordings are designed so that it is relatively easy to play specific portions. Special conditions in the classroom, such as diminishing the amount of ambient light, are not required for playing sound recordings. In these ways, sound recordings may be more easily integrated with a lesson than motion pictures.

While ordinary sound reproducing and recording apparatus may be used in classrooms, some manufacturers provide apparatus designed for schools specifically. The Victor Talking Machine Company, for example, manufactured a special spring-driven phonograph for school use. Cost was kept to a minimum by using components that were also used for other, more common models. This feature also ensured that repair and maintenance costs would be congruent with what the general public would pay. The school model *Victrola* was housed in an oak cabinet which could be, "locked to protect it from dust and promiscuous use by irresponsible people" (Victor Talking Machine Co., 1921, p. 59). An attempt was made to prolong the life of the apparatus. Supplementary books and activity materials, usually made available at low cost, were also sold by some manufacturers to assist teachers in using sound equipment and recordings to the greatest advantage in the classroom (Victor Talking Machine Company, 1921). It is likely that the features of ready availability, few safety hazards, no need of special operating conditions, costs congruent with models for the general public and inexpensive supplementary materials encouraged the proliferation of this type of teaching aid.

It has already been mentioned that sound recordings can be easily integrated into classroom activity. While it is necessary for a student to provide full attention to a motion picture, such is not always required with a sound recording. If a class listens to a recording explaining particular modeling procedure with plasticine, for example, it is not necessary for the students to provide all of their attention to the recording. Students might manipulate the plasticine simultaneously with the recording, thereby applying enactively what they have learned symbolically. Recitations of literary works permit students to use imagination to envisage the individuals and or the settings mentioned and described. Notes may also be taken by students listening to sound recordings, since the light in the classroom does not need to be diminished as with motion pictures. Some [illegible] apparatus, such as tape recorders, permit the user to record material recording capability is usually combined with other teaching aids or with specific instructional approaches. Examples will be described in a subsequent section.

Although some of the merits of using sound reproducing apparatus as a teaching aid have been described, this teaching aid does have disadvantages. While factors such as cost and the fragility of the recordings may diminish the attractiveness of using sound reproducing equipment as teaching aids, pedagogical factors appear to be more important in determining the extent to which such apparatus is used. Factors such as remoteness, permanence and random access are contended with successfully, but there is one pedagogical factor in particular that is not addressed; *constancy of use*. The teachers at a particular school may have the knowledge of how to best select and use sound recordings in their classes. Other teachers, who might not be as well trained or experienced, may not always select the most appropriate recordings, or may not be able to integrate them in their lessons in appropriate ways. In such cases, the use of sound recordings may confuse the classes or hinder their understanding of the subject. This condition appears to be especially pronounced in rural and in isolated areas where fully-trained teachers may not always be available (Morgan, 1930). While training and upgrading programs may alleviate this problem, the use of another type of teaching aid that ensures constancy of use, may alleviate the problem faster. Such a teaching aid is the radio.

Radio

Like the motion picture and sound reproducing apparatus, radio was established initially as a form of communication and public entertainment. By the early 1920s, the possibilities of using radio for instructional purposes were being investigated and experimented with (Morgan, 1930). The aspect of remoteness of experts seems to be one of the most important factors encouraging the adaptation of radio to education. Morgan (1930) states, "Radio will universalize learning ... It brings instantly to untold millions the very thinking processes of the best minds" (p. 71). This view is also shared by Darrow (1932), who states, "The central and dominant aim of education by radio is to bring the world to the classroom" (p. 79). Radio is also capable of presenting students with experiences that they might otherwise be unable to obtain, such as listening to a symphony orchestra (Watts, 1954).

While Thomas Edison and others contend that books and/or teachers will be displaced by such teaching aids as the motion picture, similar claims about radio do not appear to be as common. It seems that most educators consider radio to be a versatile teaching aid congruent with prevalent methods of pedagogy, rather than a device that is bound to alter the rôle of the teacher radically (Darrow, 1932; Harrison, 1942).

Apart from permitting the remoteness of experts, the use of radios in classrooms ensure that the teachers using them will be exposing their classes to the same material, in much the same manner as using approved printed matter. Such *constancy of use* is lacking with motion pictures and with recordings, where what is played back is subject to the discretion of the individual teacher. While constancy of use has the advantage of ensuring a common exposure of information, the principle tends to restrict innovative teachers who may possess superior knowledge, materials and methods to those presented by radio.

Although using radios in classrooms is simpler and safer than most motion picture projectors, there are technological problems to be contended with. As mentioned in a previous section, many rural schools in Canada and the United States did not have a ready supply of electricity until after the Second World War. While this condition is a major problem for using motion picture projectors, the problem is not as severe for radio. A major commercial market for radio sales were farms and small rural towns, most of which did not have electricity. To access this market, many radio manufacturers produced radios that operated from batteries. Necessary ancillary apparatus such as antennae and lightning arrestors were also readily available. The cost of such equipment for

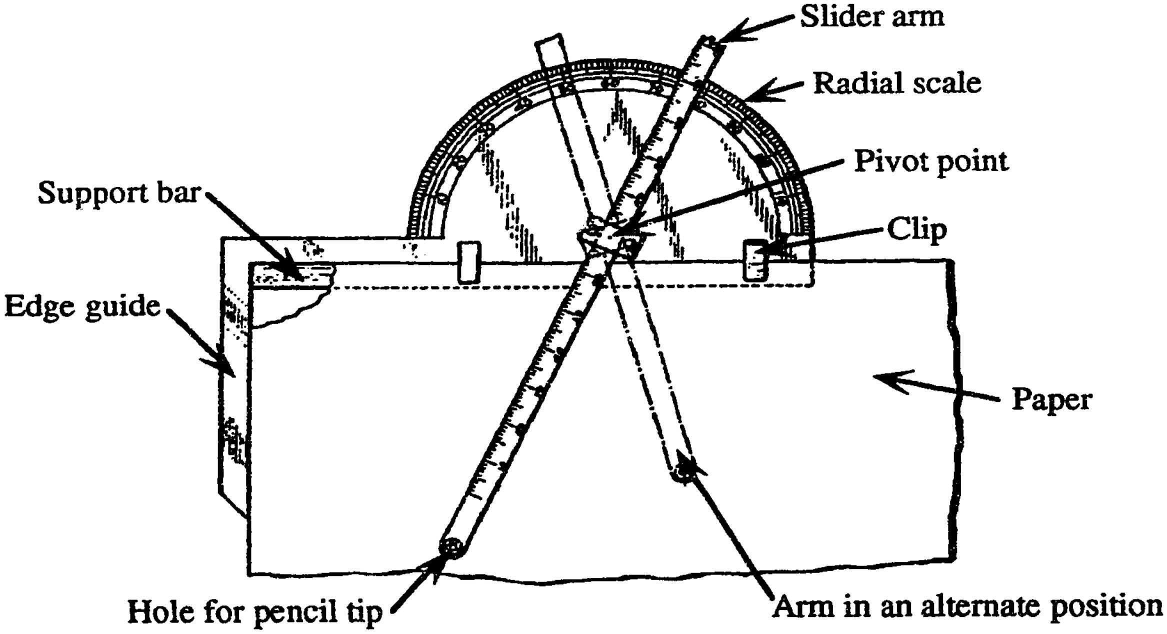
Schools could use the same equipment as that found in many homes (Morgan, 1930). In some areas, government funding was available to assist schools in purchasing appropriate equipment (Alberta Department of Education, School Broadcasts Branch, 1950)

The provision of adequate programs was facilitated both in the United States and in Canada by support from local and federal departments of education. In the Province of Alberta, for example, provision was made for the broadcast of nationally-based programs as well as for programs originating provincially. Program guides for teachers as well as for students were made available either at minimal cost or at no charge. Besides listing broadcast times of particular programs, the guides also contain suggestions for integrating the programs into lessons, and suggestions for related activities before and after each program. By limiting the difficulty of obtaining, operating and integrating radio into the classroom, teachers were encouraged to use the device as a teaching aid.

One severe limitation of radio is its inability to present an image of what is being described. While verbal descriptions may enable a sufficient understanding of certain concepts that are already familiar to the listener, some concepts are extremely difficult to relate without the use of the visual sense. To overcome this limitation, some individuals designed additional teaching aids that are to be used in conjunction with lessons presented by radio.

Fleischer's teaching aid for drawing by radio

Max Fleischer, a cartoonist and an animated film maker, created the character *Betty Boop*, and also designed a teaching aid to be used with instruction by radio. Fleischer contends that it is possible to teach the rudiments of drawing by means of radio, provided that the listeners also possess a teaching aid that will guide their hand so that marks on the paper will correspond to those of the instructor-broadcaster. While the principle of Fleischer's device is similar to that embodied in Quintilian's writing practice board, the appearance and operation of Fleischer's device is different. Figure 49 (after United States Patent Number 1,617,207, June 4, 1925) depicts Fleischer's teaching aid attached to a piece of drawing paper.



The apparatus is fabricated of metal and consists of a protractor-like radial scale that is a part of the paper support bar. The support bar also contains an edge guide so that each user may set the paper in a consistent manner. Two metal clips also help hold the paper in position. Attached to a pivot at the centre of the radial scale is a straight-edge or slider arm that is secured so that it may be slid back and forth along its length. A hole at one end of the slider arm permits the insertion of a pencil point through the arm. In use, the student places paper into the apparatus and sets the slider arm to the settings presented over the radio. By making small marks at each of the settings, and then joining the marks with either straight or curved lines, it is possible for the student to duplicate the motions of the instructor without having seen what the instructor has drawn (United States Patent Number 1,617,207, June 4, 1925).

While the practicality and the effectiveness of this type of teaching aid may be questioned, Fleischer's device illustrates how it is possible to combine two or more teaching aids to improve the overall effectiveness of the initial teaching aid, the radio in this instance. Although he did not state so, Fleischer's device represents an attempt at providing instruction almost entirely by machine. By definition, this arrangement is not a teaching machine, since instruction is provided by a teacher, albeit not present, and there is no immediate and ongoing evaluation of the student's input with consequent instructive feedback. Without such instructive feedback, it may be argued that such teaching aids are dangerous pedagogically. For example, it is possible for someone who does not correctly understand the instructions, and draws an object that is different from what the instructor intends, to believe that he or she can actually draw like the expert giving the lesson. While the potential for two-way communication by radio and telephone has existed for many years, confusion is not always eliminated with such systems, since both parties must rely upon a single system of symbols, verbal language. Verbal instructions may be interpreted by individuals differently, depending upon each individual's concepts of what the verbal symbols represent. It is clear, therefore, that without instructive feedback, additional sensory elements or symbol systems must be available to reduce the likelihood of misunderstanding. The development of another technology, one which can present visual as well as aural information, addresses this concern in part. This technology has also displaced the radio as a popular teaching aid.

Television

Although regular television broadcasts were being made in parts of the United Kingdom and in parts of the United States and Canada before the Second World War, primitive and expensive technology made it unfeasible for use as a common teaching aid. The idea of using television as a teaching aid was realized as early as 1932, however. At that time there were only 7 licensed television stations in Canada and 39 in the United States (Dunlap, 1932). Prophetically, the president of Colgate University (cited in Dunlap, 1932) states, "One cannot refrain of thinking what it will mean in education where the most noted lecturer in the country will not be confined to a single classroom or university, but while lecturing to his immediate audience he may be seen and heard in every other university in the world" (p. 261). By the 1950s, after television had become a commercial entertainment success, it was adapted for instructional purposes by many concerns. In spite of combining of the advantages of radio with the visual presentation of the motion picture, educational television was in a state of decline by the end of the 1960s (Reiser, 1987). One of the reasons for the failure of this teaching aid was stated by the president of Colgate University thirty years earlier; television was used primarily to present lectures without any provision for audience response or feedback to the lecturer. Concurring with this assessment, Reiser (1987) states, "This problem [the decline of educational television] was due in part to the mediocre instructional quality of some of the programs that were produced; many of them did little more than present a teacher delivering a lecture" (p. 17). Recent endeavors to resurrect television as a popular teaching aid appear to promote the use of commercially-produced programs such as *Sesame Street*, *The Polka Dot Door* and *The Magic Library*, that are intended to be entertaining as well as educative (*Edmonton Journal*, 1990, p. C10). It remains to be seen whether this strategy will help make television an effective and a popular teaching aid once again, since it is usually difficult to integrate such programs into most classroom curricula.

While it is possible for television to permit the remoteness of the expert, the presence of this element by itself is evidently insufficient to ensure the success of a teaching aid. This observation was appreciated by some manufacturers of teaching aids prior to the rise in popularity of instructional television, since there are other teaching aids manufactured that combine several methods of presenting information. To avoid boring students with remote lecturing or *electronic page-turning*, many of these teaching aids either have some provision for instructive feedback, or they are designed to be used by a teacher as one component of a pedagogic method or system.

During the 1950s and early 1960s, it appears that two main ideologies were prevalent concerning the design and the deployment of teaching aids. One idea is that the concepts of remoteness of the expert and constancy can be incorporated into teaching aids that may be used in traditional-style classrooms, although the students may be learning through individualized means. It is important to recall that the idea of individualized instruction is not new at this point, considering innovations such as LaZerte's *Primary number booklets*, the Winnetka plan and the promotion of individualized instruction by the progressive education movement (Ricker, 1938). The other idea is that by using the principles of individualized instruction at remote locations, teaching aids can either displace or replace the teacher. Examples of teaching aids that reflect both ideologies will be described and discussed.

Teaching aids for use with teacher supervision

Reading pacers

Among the earliest post-Second World War teaching aids to permit an individualized approach to instruction, are the electrical or mechanical *reading pacers*. These devices, introduced commercially as early as 1953, consist of a mechanism that moves a shaft outwards from a main housing. The end of the shaft furthest from the housing is connected to a metal or plastic bar arranged perpendicular to the shaft. The bar is intended to be placed on top of reading material such as books or newspapers (Audio Visual Research, 1962). In operation, the mechanism pushes the bar away from the housing at a controlled rate of speed, thus obscuring lines of text as it progresses. The speed that the bar travels may be set by controls located on the housing. It is contended that the movement of the bar will force students to read faster or miss lines of text, which will result in motivating the student to improve reading speed (Audio Visual Research, 1962). These devices are intended to be used under the supervision of a teacher who ascertains the best speed of the device for each student (Americana Interstate Corporation, 1966).

While such teaching aids may be useful in providing guided practice to students who are trying to increase their reading speed, the devices do little to aid those individuals who have difficulties in recognizing particular letters or words, or individuals who have not learned proper eye movement in reading. As well, the construction of the devices makes them susceptible to damage. To overcome these limitations, some enterprises have combined two or more discrete teaching aids to get a single teaching aid that overcomes problems experienced with simpler, less complex models.

Combination teaching aids

To permit individualized instruction in traditional classrooms using modern combination teaching aids, manufacturers have had to simplify the operation of the aids to enable students to operate them with a minimum of training and difficulty. To be effective for individualized instruction, teaching aids must be designed so that their use does not disturb other students with noise, or require the reduction of ambient light levels in the classroom. Considering these factors, several manufacturers have developed combination teaching aids for use in traditional classrooms, either by the teacher or by individual students.

Tachistoscopic teaching aids

An example of such a device is the *Craig reader*, designed to enable students to gain facility and speed in reading by combining written symbols with visual presentation (Craig Research Inc., 1961). Unlike many older reading pacers that are susceptible to damage and which can only obscure lines of text, the Craig reader combines written symbols with a method of projection to aid instruction in a variety of areas. The apparatus consists of a compact housing that contains a viewing screen, light source, projection lens and a control mechanism. The printed material to be viewed consists of photographic slides that are contained in one or more plastic frames that may be inserted into the machine (Craig Research Inc., 1961). The Craig reader may display particular lines of text for a given period of time. While this function is similar to what is done by reading pacers, the Craig reader limits eye movement further, since it displays only one line of text at a time, obscuring previous and subsequent lines. The control mechanism also permits the apparatus to alternately illuminate and darken the viewing screen rapidly, thus providing tachistoscopic practice in letter or word recognition (Craig Research Inc., 1961). While devices of this variety function as teaching aids for specific conditions and subject areas, there are other modern teaching aids that combine several discrete teaching aids so that they may be used for a wider variety of applications.

Audio-visual teaching aids

In the 1960s, the DuKane Corporation introduced an audio-visual teaching aid for individualized instruction within classrooms. The apparatus, called the *A-V Matic*, is a combination single-speed phonograph and 35 mm filmstrip projector with an integral viewing screen. Earphones are available at extra cost. The device is arranged to operate automatically once a filmstrip is loaded and a special record with sonic pulses is started. The pulses trigger a mechanism within the apparatus which causes the filmstrip to advance. Provision is made for the user to hold the program at any point and then to resume progress when ready. Once the end of the record is reached, the machine rewinds the filmstrip automatically, although to start the presentation again, it is necessary for one to move the tone-arm of the record player to the beginning of the record (DuKane Corporation, 1966). While the machine appears to meet the requirements necessary for individualized instruction within a classroom, simplicity of operation, compact size and no need for a special operating environment, the device has not gained universal use like the blackboard. The most probable reason for the limited use of the A-V Matic, is that no prepared instructional packages were made available initially. It was up to the customer either to design presentations or to locate suitable material. Few teachers possess the time or the inclination to design such material if they are performing their other duties diligently. As well, the cost of producing and manufacturing suitable course materials is probably expensive enough to dissuade many school boards from investing in the apparatus to begin with. The problem of suitable and inexpensive course materials was consid-

A similar device, called the *Show 'N Tell Picturesound Program*, manufactured by General Electric and the Taylor-Merchant Corporation, contains a multi-speed phonograph and a 16 mm film projector. Unlike the DuKane apparatus, the General Electric device was sold with a number of educational programs as well as childrens' stories (New Application for General Electric Device, 1965). The appearance of the device resembles a television set, possibly a marketing strategy to capitalize on the educational television movement of that time. Like the DuKane apparatus, the General Electric *Show 'N Tell Picturesound Program*, did not gain widespread use.

Similar devices were marketed by other enterprises. One example is the *A V Projector*, manufactured by Hoffman Information Systems. The apparatus is similar in appearance to the DuKane A-V Matic, but the Hoffman unit uses colour slides rather than filmstrips (Hoffman Information Systems, 1967). A quantity of prepared presentations, covering a number of different subject areas, were available with the A V Projector. The device is intended to be used primarily by teachers. It does not appear that this apparatus can be used for individualized instruction. One of the major advantages of this teaching aid, as stated by the manufacturer, is that it will motivate students through attention-focussing attributes such as "engrossing narration" and slides that are "artfully prepared" (Hoffman Information Systems, 1967, p. 63). The Hoffman A V Projector does not appear to have been any more successful than the other two devices discussed previously. It seems that an additional element is lacking in such teaching aids to make them effective and, therefore, more desirable.

One element that some devices incorporate is *feedback*. Unlike teaching machines, that provide instructive feedback based upon the user's input, these teaching aids do little or nothing with the user input to govern the type of feedback that is provided. Examples of these teaching aids include specialized recording and playback devices such as large language laboratories as well as smaller units such as modified tape recorders and magnetic card readers.

Prime-O-Tec system

This approach to reading instruction is an example of the use of a modified tape recorder as a teaching aid. The apparatus consists of a tape recorder, in this instance a reel-to-reel model, and a junction box that permits a quantity of headphones to be connected simultaneously. The teacher prepares the instructional tapes by recording either pre-primer material or primers word-for-word (Jordan, 1966). In use, the students either look at or read their printed instructional materials while the tape is played. By having the students recite particular passages, the teacher can ascertain which students are having difficulties with the lesson. When no difficulties appear to be present, the teacher may spend time with other students in the class who are not connected to the tape recorder (Jordan, 1966). While Jordan (1966) states that such methods are usually not essential with most students, he also states that the Prime-O-Tec system is especially useful in classes that contain students with reading problems such aphasia and dyslexia. With such students, Jordan (1966) claims that the headphones isolate the student from the classroom, so that attention is focussed on what is being presented. It is emphasized, however, that the Prime-O-Tec system is a teaching aid and that it is not intended to be a substitute for a teacher. Although the Prime-O-Tec system of instruction itself may not be in use at present, similar systems continue to be used in many schools in North America. Such systems do not facilitate individualized instruction within a classroom, however. Where individualized instruction of this variety is desired, there is a class of teaching aids available that are referred to generally as magnetic card readers.

Magnetic card readers

Magnetic card readers appear to have evolved from language laboratories and specialized tape recorders developed in the 1950s. An example of the latter is the *Add-A-Track* tape recorder manufactured by V-M Corporation. With most ordinary tape recorders, one may alternatively record or play back information. The Add-A-Track model permits information to be recorded in such a way that it may be played back simultaneously with what was recorded initially. Through this form of user input and feedback, it is contended that learning can take place by the user comparing the original recording with subsequent recordings (V-M Corporation, 1960). A limitation of such specialized tape recorders is that they do not provide enough information for some subjects. If it is intended to teach words of particular objects, then the tape recorder by itself is usually insufficient. Books may be used in conjunction with the machine, but the possibility exists that a student will associate the wrong word with an object. Such errors will require subsequent *unlearning* when discovered. An apparatus that contains both pictorial and recorded information may reduce the likelihood of such confusion.

Most magnetic card readers consist of a specialized playback unit that also permits recording. The playback unit or reader is designed to use special cardboard or plastic rectangular cards. The cards are printed with pictures and/or words. A magnetic strip is also placed along the length of the card, near the bottom. The magnetic strip contains recorded information as well as space for recording additional information. In operation, the card is inserted into the reader. Depending upon the manufacturer, the reader will either scan the card without moving it, or the card will be drawn slowly from right to left. During scanning, the information on the magnetic strip will be reproduced. By depressing a key or by moving a lever, the user may record information onto the magnetic strip. The next time that the card is scanned, both recordings will be reproduced, enabling the user to compare them (Teaching Technology Corporation, 1967).

Bell and Howell's *Language Master*, introduced in 1964, is one of the first examples of a magnetic card reader intended for classroom use (Bell & Howell Introduces "Language Master", 1964). Bell and Howell state that the reason they introduced the Language Master is that there is a need for it. As well, their field tests indicate that the Language Master is an effective teaching aid for a variety of subjects, both with ordinary classes and with classes consisting of students with special needs and deficiencies (Bell & Howell Introduces "Language Master", 1964). It may be argued that the perceived need for the Language Master was contrived and that the validity of the studies done is questionable, given that the primary purpose of a company is to sell its products or services. There is evidence to show, however, that there has been a sustained market for the product, indicating that it does address an actual need. Firstly, models of the Language Master continue in production (personal communication with Eiki/Bell & Howell, December 1988). Secondly, other enterprises have introduced similar products to take advantage of the market.

One example is the model manufactured by Teaching Technology Corporation. While there is close similarity with Bell and Howell's Language Master, Teaching Technology's version does not move the card to play the magnetic strip (Teaching Technology Corporation, 1967). It is contended that this feature makes the Teaching Technology model superior to models that move the card, since a stationary card facilitates reading the material printed on the card (Teaching Technology Corporation, 1967). While the speed of cards through the Language Master and similar models is slow enough that it is unlikely that most individuals will have difficulty tracking the text, individuals with reading disabilities may find that the movement adds difficulty to reading. Although magnetic card readers continue to be manufactured, factors such as cost and their integration within the classroom have prevented this type of teaching aid from being used as extensively as the blackboard.

Most of the modern teaching aids mentioned to this point require a teacher to be present with the teaching aid, either to prepare the apparatus for each particular student, or to provide information and supervision. There are some modern teaching aids that are designed to function as a *teaching system* that may be used without the presence of a teacher.

Teaching aids that do not require the presence of a teacher

A major feature of most audio-visual teaching aids that prevents them from working effectively without the presence of a teacher, is their inability to ascertain whether the student is actually attending to what is being presented. It is necessary to have a teacher present, therefore, to supervise the interaction with the teaching aids and to provide appropriate instructional feedback. Teaching aids that can accept student input and relay that information accurately to a teacher for analysis and then are able to present appropriate instructional feedback to the student, may be used without having a teacher present. It is important to note that such devices are not teaching machines since it is a teacher, not the machine, that analyzes student input and provides the instructive feedback. Although a few early twentieth century devices, such as Page's apparatus for teaching telegraphy, are designed to be used without a teacher present, it was not until the 1950s that many teaching aids of this sort were devised and marketed. To be sure, courses of study employing various means of correspondence have been available for many years, but most of these programs do not use teaching aids as a major component.

Transpondence

An example of a teaching system that may be used without the presence of a teacher, is the method of *transpondence* marketed by the De Forest-Sanabria Corporation in the 1950s. This method is intended to enable adults to learn in their homes, the basics of television broadcast, reception and technical repair. Each student receives a package of materials that includes a reel-to-reel tape recorder called the *transponder*, tapes of lectures, film strips, a film strip projector and supplementary books and pamphlets (De Forest-Sanabria Corporation, 1951). In use, the student plays the tapes in sequence and also projects film strips as directed in the tape. It is claimed that the projected images emulate a blackboard. While it is widely held that taped lectures induce boredom, the company seems to ignore this observation, claiming instead that their approach is superior pedagogically to classroom methods, "It's even better than the classroom, because you can repeat the instructor's lectures until they are thoroughly understood" (De Forest-Sanabria Corporation, 1951, p. 7). To overcome the problem of no instructor feedback, the tape recorder is equipped with a microphone so that the student may make recordings. An advertisement states, "Tell your instructor about anything that puzzles you and get his answers back pronto" (De Forest-Sanabria Corporation, 1951, p. 7). This method of student input and instructor feedback is similar to Page's apparatus for teaching telegraphy by correspondence.

With both methods there is considerable delay between the student input and the instructive feedback, since the tapes must be sent away to be evaluated. Once examined and instructive feedback is provided, there is a further delay while the tapes and comments are returned. Such delays tend to prolong the length of the course. Protracted delays may also confound the understanding of subsequent lessons, especially in a hierarchical presentation where subsequent learning is largely dependent upon the comprehension of antecedent concepts. In extreme instances, the student may not be able to proceed with lessons until a response is received to the question, by which time the student will likely have forgotten further information and concepts. While these teaching aids used in this way facilitate remoteness of the expert, additional pedagogical problems are intro-

There is an implicit assumption with this method of instruction, that the student already possesses the knowledge and the ability to comprehend the information provided. If, for instance, a student possesses a low level of reading comprehension, then the supplementary reference materials will be of little use. Such instructional materials also assume a particular base-level of knowledge. A base-level that assumes no prior knowledge of scientific principles and notation, will probably bore a student who already possesses such knowledge. Setting a base-level that is too high, assuming that the concepts of magnetism or the meaning of the term *electron* are understood, for example, may result in some students being unable to comprehend most of the information presented by the tapes and filmstrips. Another problem with the method of transpondence, is that it is based entirely upon iconic and symbolic information. While the tapes, filmstrips and printed matter describe and illustrate principles of operation as well as diagnostic and repair procedures, no provision appears to be made for the transfer of this iconic and symbolic knowledge to an enactive or practical setting. To describe soldering and to supplement the description with pictures, for example, is unlikely to lead to a student either fully comprehending the procedure, or being able to transfer what was learned through observation and symbol comprehension into proper enactive procedure.

While the method of transpondence does present expert information through a variety of means including printed matter, problems such as delay in instructive feedback, the assumption of student skills and prior knowledge, and the absence of transforming abstract concepts into practical skill, are likely major reasons why this approach has not become popular. Other correspondence-type approaches try to address this problem by using other teaching aids.

National School's shop method home training

Recalling Bruner's (1964) hierarchy of encoding, it is contended that there is a natural progression from *enactive* manipulation of objects, to *iconic* representations and then to abstract *symbolic* representations (p. 2). A similar hierarchy seems to have been appreciated by some enterprises that offer instruction in electronics at home. As early as 1951, National Schools of Los Angeles, California, developed a method by which one may learn the principles of electronics as well as radio and television repair through enactive means. An advertisement claims that, "you learn by doing" (National Schools, 1951, p. 37). Instead of taped lessons and filmstrips, the student is supplied with printed course materials and a box of components. If the student is successful in following the lessons, then he/she will be able to construct a functional superheterodyne radio receiver from the parts provided. The advertisement does not state what a student does if problems are encountered with either the course material or with construction of the radio. As well, if the student simply follows the assembly instructions, in an *assembly-by-number* sequence, then it is doubtful if much electronic theory is learned by constructing the radio. While there are electronic home construction kits marketed by firms such as Heathkit and Philips, no claim is made that the builder of the kit will learn either the principles of operation or principles of electronics. Depending upon the complexity, some kits recommend that the builder have soldering skills and/or particular specialized knowledge.

A problem also exists in evaluating completed practical work not done in a supervised environment. The student may end up with a functioning radio, but this fact does not indicate that sub-skills such as soldering have been done properly. Allion (1958) mentions this type of problem and notes that some enterprises, such as an upholstery trade school, evaluate the finished product by means of a photograph submitted by the student. It seems unlikely that a photograph can provide sufficient basis for an instructor to make a fully accurate assessment of the student's proficiency. There is also an assumption by the correspondence school that the photograph submitted is of the student's work and not a photograph of a commercially-produced item or the work of someone individuals who already work in the areas concerned. Besides ensuring a particular base-level of knowledge among the students, such restrictions may help to minimize the likelihood of students submitting fraudulent photographic proof of their skill.

While it seems that the use of teaching aids as a major part of correspondence or self-study programs is inferior to classroom methods, self-study methods that use teaching aids continue to be marketed. It might appear that the novelty of some of the teaching aids, or their names, are effective sales strategies. This point is contested by Allion (1958) who contends that, "No good self-study or home study course includes them [teaching aids] simply as 'gimmicks'... There is always a teaching *reason*" (p. 14). She does not define what a *good* self-study program is. As well, no quantifiable evidence is cited to indicate that the inclusion of such teaching aids actually results in an improvement of student learning over simpler, less expensive correspondence methods.

Another possible justification of using teaching aids in self-study courses, is that such methods are necessary for particular segments of society. For example, Allion (1958) notes that self-study methods may be the only way that adult illiterates may learn to read, since many of them, "are often too shy and embarrassed to attend classes" (p. 14). While there are advantages to using self-study programs that use teaching aids, there are some programs that seem to use teaching aids solely as a *gimmick* to help sell the program. A common variety of this type are those programs that promote learning through *subconscious* means.

Electronic educator

An example of this approach is a program and teaching aid sold as the *electronic educator*. It is marketed by the Sleep-Learning Research Association of Olympia, Washington. The underlying theory of this method is that learning can take place when one is asleep (Sleep-Learning Research Association, 1962). The apparatus consists of a tape recorder, a microphone, several speakers and a number of special tape cassettes that have the tape arranged in a continuous loop. While the tape recorder can be used in traditional ways, it is primarily intended to be set up to play while the user is asleep. An advertisement states that the special tape, "repeats itself and your message endlessly to give you the necessary repetition to memorize material" (Sleep-Learning Research Association, 1962, p. 46). While the efficacy of repetition is questionable, as discussed previously, there are scientific findings that conclude that one is not capable of attending to sounds, except for loud irregular noises, while asleep (Coleman, 1986). Given the lack of quantifiable scientific evidence to the contrary, it seems that the efficacy of this type of teaching aid is dubious at best. In spite of such criticism, many sleep-learning tapes and programs continue to be sold, not only through advertisements in periodicals, but in stores as well (author's observations). It is likely that many lay-people believe that they can learn while they sleep. A sustained market from this segment of the population is probably why such teaching aids continue to be manufactured.

Tele-Lecturing

It has been mentioned previously that a disadvantage of teaching aids that permit remoteness of the expert, is enabling the expert to obtain feedback from the audience to avoid boring or confusing them. One common device that permits such interaction is the telephone. While the telephone is used for two-way communication between an instructor and a class by some institutions in North America, its effectiveness is hampered by its nature. Like the radio, neither the speaker or the listener can see what the other is doing. It may appear that this limitation is of concern only with subjects that rely upon the visual sense. An absence of any visual communication may also be detrimental generally.

the instructor may ask questions of specific students to ascertain whether or not they have been paying attention, there is nothing to indicate whether the student answering is receiving assistance from other students. Group discussions are not suited to the telephone, even if provision is made for each student to have a hand or headset. Without visual cues, it is difficult for an instructor to distinguish individual voices if several students speak at once or in close succession. Limiting speakers to one at a time may stifle spontaneity and discussion as a whole.

The cost of using the telephone is a major factor that determines its use as a teaching aid. Although telephone apparatus is ubiquitous in North America and Europe, and is usually inexpensive, to have several telephones in a classroom usually requires the installation of cables and may also require the installation of special equipment. Further costs are incurred through toll charges. While fixed rates may be arranged in some instances, the total cost of the apparatus, installation and tolls tend to discourage extensive use. One way of defraying costs is to present instruction to more students at once. While it is possible to use a telephone to deliver information to 100 students at a time, the method does not facilitate student response. To reduce the cost factor and to permit easier student response, some enterprises use another type of teaching aid for distance education.

Educasting

A logical development from using ordinary amplitude modulation (AM) radio as a teaching aid, is to incorporate some means of accepting student input. While commercial broadcast frequencies are not suitable for two-way communication, there are many frequencies that are available for this purpose. In the mid 1960s, International Correspondence Schools of Scranton, Pennsylvania began to use four frequency modulation (FM) sub-carrier frequencies for two-way instructional radio. This teaching aid system is called *Educasting* (Broadcasting system permits student feedback, 1966). The sub-carrier frequencies are provided by a commercial FM station. The sub-carrier broadcasting does not interfere with the programming of the commercial frequency, so the host station does not lose any potential advertising revenue (Broadcasting system permits student feedback, 1966). Using a special FM receiver with four push buttons to access the various sub-carrier frequencies, at least 100 students at one time may receive radio lessons. One sub-carrier is used by the teacher, while the other three are available for student response. The three sub-carriers, unlike a single telephone line, permit more than one student at a time to respond. Like the telephone, two-way radio communication is capable of providing immediate feedback.

Although initial trials of the educasting system appear to have been successful, the cost of the apparatus, the sparse number of FM transmitters, the limited range of operation caused by the low power of the student transceivers, as well as difficulties in securing coöperation with commercial stations, are likely factors that prevent this type of teaching aid from gaining much use. Like the telephone, interactive radio is not appropriate with subjects that require extensive visual information. Many school subjects such as mathematics and chemistry rely heavily upon diagrams and equations that are written by the instructor as the lesson proceeds. A visual component is necessary in such instances, but as we have seen with educational television, there must also be provision for student feedback to avoid boredom and confusion. Teaching aids have been developed to overcome this limitation as well as cost, but the factor of reliability has limited their deployment.

Electrowriter

Combining the technology of analogue facsimile machines, the telephone and the overhead projector, a teaching aid known as the *electrowriter* was developed to enable remote audiences to observe whatever the instructor wrote. Developed by General Telephone & Electronics Corporation (GTE) and tested in the early 1960s, the apparatus consists of a rectangular housing that holds paper as well as electronic gear. A special pen that contains a pressure switch and a small electromagnet is attached to the housing by a wire. This *master* unit translates the movements of the pen into varying voltages which are then transmitted by telephone as a varying sound pitch to a *slave* unit at a remote location. The slave unit consists of a rectangular housing that holds clear plastic sheets and a pen that is attached by stiff wires to a system of solenoids. The slave unit is intended to be placed upon an overhead projector (Trotter, 1965).

To use this teaching aid, at least two telephone lines are required, one for use by the instructor and students, the other for use by the electrowriter machine. The instructor uses the special pen to write or draw onto the paper in the master unit. An identical image is then drawn on the plastic sheet in the slave unit (Trotter, 1965).

Trotter (1965) states that it is not necessary to have the instructor present to use this teaching aid. By using a stereo tape recorder, verbal information may be recorded on one track, while the other track records the sounds created by the electrowriter. This method of instruction facilitates permanence of the lesson, in a manner similar to regular recordings and motion pictures. Using the electrowriter in this way precludes response from students and immediate instructional feedback from the instructor. Although this teaching aid adds a visual component not present with radio or straight telephone communication, the apparatus is particularly vulnerable to technical problems. If, for example, the pen on the slave unit fails, then aspects of the lesson will be lost. Although the pen may be repaired or replaced, time is lost. The slave unit may not function properly if the telephone line used contains interference. Instead of drawing what the instructor draws, the pen on the slave unit may move randomly or it may move to an area of the plastic that has already been written on. A device that is prone to technical difficulties will not be relied upon and may be considered a hindrance rather than an aid.

It may be asked why this variety of apparatus was developed, given that television was both a popular and a reliable system. The factors of cost, available infrastructure and a lack of suitable programs, appear to be the predominant reasons why television did not become a ubiquitous teaching aid (Rainsberry, 1964; Trotter, 1965). Although the electrowriter may not be robust technologically, it is less expensive than television and it is not dependent upon prepared programs. This factor continues to be a significant consideration in the deployment of modern teaching aids. While digital facsimile machines have been introduced that eliminate most of the technical problems that beset the electrowriter, the cost of the apparatus as well as toll charges on telephone lines continue to be factors limiting their use.

Conclusions

This chapter has described and discussed the development of teaching aids in the twentieth century. Although there are more examples of teaching aids than have been described, it has been shown that there has been a proliferation of teaching aids as well as an increase in their use by educators, both within classrooms and in other educational settings. This point may be supported further by considering the number of professional and scholarly articles about teaching aids that have been published each year. Figure 50 (compiled from data in *Education Index*) depicts the number of articles published on teaching aids each year in periodicals reviewed by the index, from 1929 through 1989. It is important to note that there may be articles that are not included because of errors in compilation or because particular periodicals may not be reviewed.

It should be noted that the fluctuations in the number of articles published per year do not necessarily reflect short-term changes in interest. Rapid declines may also be explained by the introduction of new categories such as teaching machines and educational television. It is clear from Figure 50, however, that there has been a general increase in the number of articles about teaching aids, and it is likely that this increase also reflects

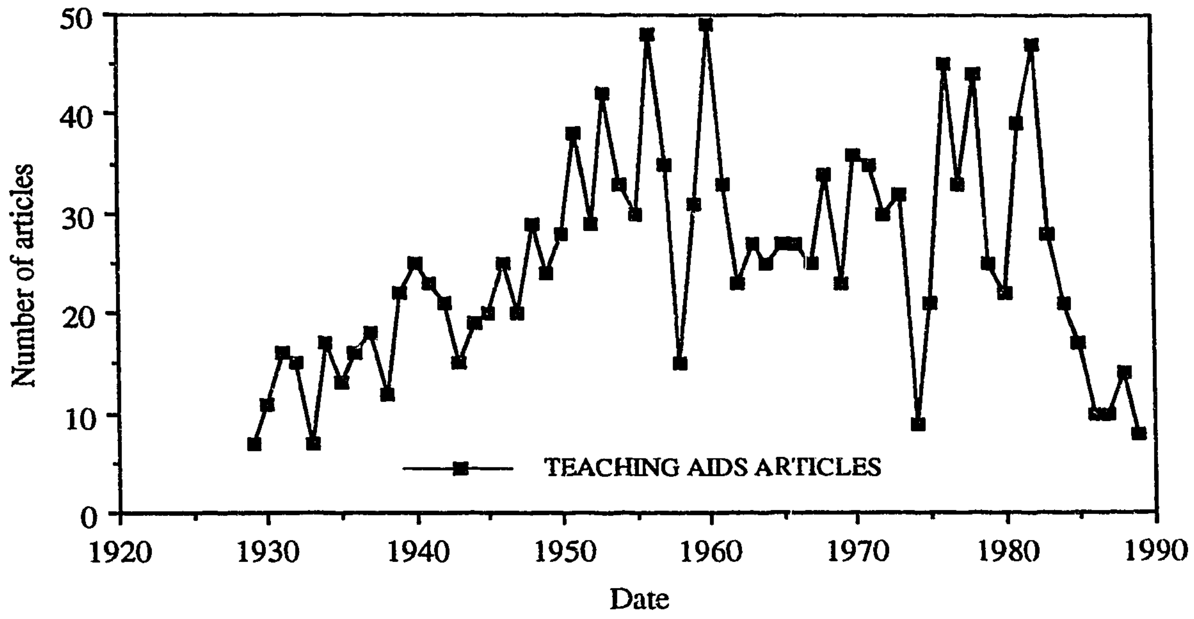


Figure 50. Number of articles on teaching aids listed in *Education Index*

more interest in them. It is not certain whether the apparent decrease in articles published toward the end of the century reflects a decline in interest in teaching aids generally, or whether other instructional devices such as the computer have been replacing teaching aids.

This chapter has also shown that most teaching aids reflect particular learning theories, whether they are appropriate or not. Factors such as cost, profit potential for the manufacturer and technical reliability appear to be significant as to whether or not a particular teaching aid gains widespread use. In some instances, it appears that the factor of profit rather than pedagogical efficacy is the main reason why particular teaching aids are introduced and promoted (Soles, 1963). The factors affecting the introduction, use and ultimate fate of instructional devices will be discussed further in Chapter IX.

While teaching machines are not discussed in this chapter, the development of some teaching aids that embody the attributes of remoteness of the expert, individualized instruction, constancy of instruction and permanence of the lesson, seem to prepare the way for the reintroduction of the teaching machine. Factors that led to the increased use of particular teaching aids such as shortages of teachers, poor quality of available teachers and large classes with several grades, also encouraged the reintroduction of teaching machines. While the devices discussed in this chapter are considered teaching aids because they are unsuccessful in eliminating the teacher altogether, teaching machines have been developed during this century that provide instruction in such ways that feedback and instruction from a teacher are not required. The next chapter will describe and discuss some of these teaching machines and the learning theories that they embody.

Chapter VI

Teaching machines in the twentieth century

Introduction

The reasons why teaching machines were reintroduced in the twentieth century are discernible by considering past developments, prevalent factors and the apparent perceived needs at the time. Many accounts written during periods of the twentieth century when the development and use of teaching machines were highly contentious and emotional issues, frequently provide erroneous or misleading accounts of the development, purpose, applicability and effectiveness of these devices. Some authors of the time including Lumsdaine and Glaser (1960), and Corey (1967) do not try to address these issues at all. Many of their contemporaries, however, provide some explanation about the origins, development and the future of teaching machines in the twentieth century.

Three general explanations of the origins of twentieth century teaching machines are predominant in the literature. One explanation, presented by authors such as Skinner (1954); Brooker (1957); Weimer (1958); Finn (1960); Broudy (1962); and Moore (1965) contends that the development of modern teaching machines was induced by rapid technological development in society generally. The basic thesis is that because other areas such as transportation, communication and food preparation have become mechanized, it follows that teaching should be as well.

Others, such as Foltz (1961); Kneller (1962); Lawson (1973); Saettler (1979); Jonassen (1987) contend that modern teaching machines are the embodiments and natural evolution of earlier theories of learning, some of which date from ancient times. These authors contend further that it is primarily because of modern technology, unknown and unavailable to the ancients, that it is possible to invent machines that can embody and realize such theories of learning. This view has resulted in some apparatus receiving ancient-sounding names such as *Plato, Socrates, didac* and *tutor*. In this way, it is possible to provide a notion of stability or of roots in tradition for these devices, so that they might be accepted by educators readily.

A third common explanation of the origins of twentieth-century teaching machines, is that they either were devised solely in this century by individuals aware of contemporary theories of learning and who attempt to *improve* instruction by creating machines that embody these theories of learning, or that these teaching machines are improvements of crude nineteenth century devices that, by their flimsy nature, were not accepted by most teachers. Accounts by Arnett, Trout and Clarke (1962); Green (1963); Austwick (1964); Kay, Dodd and Sime (1968); and Benjamin (1988) exemplify this type of explanation. Which of these explanations, if any, is correct and why?

While elements of the first two explanations, development of modern technology and its pervasiveness, may explain in part why some modern teaching machines are complex devices, all three explanations omit many factors. These omissions are likely the result of ignorance of earlier developments, technology, theories of pedagogy, and the tendency of many contemporary educators to believe that what they consider to be new or novel could not have existed previously. This view implies that any earlier developments, if they should be discovered, are of little concern to the development of *new* and *modern* devices. While the twentieth-century designers of many teaching machines and the learning theories that they embody were probably ignorant of ancient and mediæval teaching machines, many of the factors that affected the use or the abandonment of earlier devices knowledge of pedagogy or from a theoretical basis, even though many of these theories and practices are not codified in the manner of most modern theories and practices. It is also apparent from previous chapters, that the development and the use of teaching machines has not followed a linear path. Moreover, while some ancient and mediæval teaching machines were simple affairs compared to the complex machines capable with current technology, for their time, many early teaching machines used the latest technology then available. Factors other than technology, such as the dissemination of information and ideas, changing pedagogical needs, political and religious influence, and financial factors especially, contributed to the discontinuance and to the obscurity of many early teaching machines.

Teaching machines in the twentieth century have not evolved directly from ancient theories of learning, nor have they arisen solely from the influence of modern developments in technology. It is noted in Chapter V, that general awareness of and interest in teaching aids increased throughout the nineteenth and early twentieth centuries. It is likely that this increased interest in teaching aids, due in part to perceived need, also had an influence on many learning theorists and educators. Saettler (1968) for example, suggests that Montessori's work probably influenced subsequent educators. Heines (1988) notes that the theories of Edward Thorndike probably induced some educators to produce innovations. Neither author, however, seems to be aware that both Montessori and Thorndike were themselves influenced by earlier work as well as by prevalent contemporary methods of pedagogy. From information in chapters IV and V, it appears that the *zeitgeist* of late nineteenth and early twentieth century pedagogy was that instructional devices that facilitate teaching and learning should be used and developed. It is likely, therefore, that the reintroduction of teaching machines in the twentieth century came about as the result of developments and interest in teaching aids.

This chapter will identify and describe some major developments of teaching machines in the twentieth century and the learning theories that they embody. Similarities and differences between modern teaching machines and ancient examples will also be noted.

It is stated in Chapter V, that an important as well as a common reason for using teaching aids is to facilitate the teacher in attending to the needs of all students in a class. A similar reason existed for using the quintain in ancient times; a centurion could not always supervise the training of 100 soldiers adequately. The quintain, as well as other teaching machines and teaching aids, continued to be used because they addressed a perceived need, and because they were demonstrably effective in providing instruction or assisting with its presentation. The rise of Educational Psychology in the nineteenth century as well as the dissemination of learning theories such as those of Montessori and Thorndike, also had an effect upon North American education in general.

Edward L. Thorndike

It is mentioned in Chapter V that Thorndike both sanctioned and promoted the use of teaching aids to facilitate the instruction of concepts. Although it appears that Thorndike was unaware of any teaching machines, he makes a statement describing a particular theoretical device that would be congruent with his theory of learning and which would also improve the learning habits of pupils. Thorndike (1912) claims that while the purpose of most text books for primary schools is to guide the learner so that he/she is able to gain the most information from the text, he notes that few text books appear able to do this well.

A book that contains discrete portions of information followed by experiments and questions, and which is also arranged to prevent the student from proceeding until the

> If, by some miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print. (p. 165)

Although teaching machines that can do what Thorndike desired were developed in the twentieth century, he did not invent them. It seems likely, given the development of teaching aids described in Chapter V and Thorndike's demonstrated limit of mechanical ingenuity, that he was influenced, in part at least, by the proliferation of various teaching aids, some of which attempt to displace the teacher.

It is noted in Chapter I that many authors state that Sidney Pressey was responsible for the first teaching machine produced in the twentieth century. At least one author disagrees with this view. Lawrence Stolurow (1961) notes devices produced before the 1920s. A search of relevant literature corroborates Stolurow's findings.

Ordahls' modified typewriter

Ordahl and Ordahl (1915) describe several devices used as aids in their experiments to ascertain differences between levels of intelligence in *feeble-minded* children. Most of the devices described are not intended to provide instruction and appear to be diagnostic aids that are used in conjunction with questions by the examiner. One exception is a device called the *modified typewriter*. While it was intended to be part of a diagnostic experiment, a component of the experiment includes the subject learning a connected series of hand-eye movements and pattern recognition (Ordahl & Ordahl, 1915). The apparatus used consists of a small box-like housing containing a number of coloured panels and which also holds four typewriter-like keys. The action of pressing a key causes a particular coloured panel to be pushed up through a slot in the top of the housing. The panel retracts into the housing as soon as the key is released. The surface of each key is covered with a particular colour. The colour on the key does not correspond to the colour of the panel that it raises (Ordahl & Ordahl, 1915).

It is intended that the subject places the first two fingers of the left hand on the first two keys and the corresponding fingers of the right hand on the final two keys. The subject is directed to press one key, observe the colored panel displayed, and then to release the key. The subject is then required to press the key corresponding to the colored panel displayed by the first key press. This process continues through all the key presses and is repeated until the subject is directed to stop. An electric counter attached to the apparatus records each key press by the subject. The examiner records the number of incorrect key presses (Ordahl & Ordahl, 1915). After a period of practice, the coloured panels as well as the colours on the keys are obscured and the subject is required to perform the pattern of key presses without the benefit of visual cues. It is assumed by Ordahl and Ordahl (1915), that if the subject is able to press the keys in the correct pattern, then he/she has learned the pattern from the device.

While the findings of Ordahl and Ordahl (1915) suggest that learning does take place in subjects using the modified typewriter apparatus, the authors do not seem to consider that such a device might be useful as a teaching machine solely, rather than as a combination teaching machine and diagnostic aid for laboratory use only.

English's teaching machine

It is noted at the outset of this chapter that one of the most successful and long-lived teaching machines is the quintain. One of the first devices designed in the twentieth century as a teaching machine was also devised for military training. This modern de-ended the First World War (English, 1942). English, who was in the United States Army at the time, notes that a major problem in teaching recruits how to shoot a rifle properly is to stop them from jerking or pulling the trigger. A rapid movement of this sort tends to pull the gun upwards, resulting in poor accuracy. While sergeants and other trainers supervised the training of recruits, like centurions in the Roman armies, it was not possible for a trainer to supervise every individual recruit at once. Many trainees, therefore, did not learn to manipulate the trigger gently. Their ability to hit a target accurately was poor, consequently. Bearing these considerations in mind, English designed a teaching machine that would instruct the recruit to squeeze the stock of the rifle so that the trigger could not be jerked or pulled.

Although some authors, notably Porter (1957) Foltz (1961) Stolurow (1961) and Carr (1962) note the existence English's device, descriptions are either lacking altogether as in the case of Foltz (1961) and Stolurow (1961) or the description provided is incorrect (Porter, 1957; Carr, 1962). While English's device is intended to teach recruits to fire a rifle without jerking or pulling the trigger, the apparatus was designed to react to the pressure of the second, third and fourth fingers, not to the actions of the index finger (English, 1942). Figure 51 (based on English's description) is the probable appearance of English's teaching machine for shooting, as installed in a United States Army Springfield rifle.

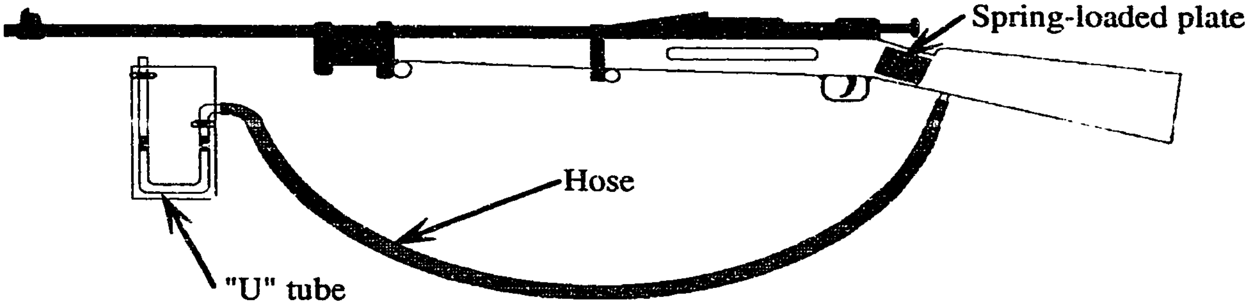


Figure 51. English's teaching machine for shooting

The apparatus consists of a rubber bulb, a length of flexible tubing and a glass "U" tube or manometer that contains some liquid coloured so that it is readily visible. The bulb is housed in a cavity formed in the stock of the rifle. The cavity is located so that the second, third and fourth fingers will extend over it. A plate, held in position by strong springs, covers the cavity. The springs permit the grip of the second, third and fourth fingers to squeeze the plate which in turn squeezes the bulb. The bulb is attached to the hose so that a tight connection is formed. The other end of the hose is attached to the "U" tube. The action of squeezing the bulb compresses air located in the bulb and the connecting hose. The pressure of the air causes the liquid in the "U" tube to rise in the left-hand leg of the tube.

In use, the recruit aims the gun in the instructed fashion, squeezing the stock with the second, third and fourth fingers, and then squeezes the trigger with the index finger. If the procedure is done properly, the liquid in the left-hand side of the "U" tube will rise considerably, indicating that the recruit is squeezing the gun stock before pulling the trigger. A further indication of correct procedure is a stable level of fluid in the left-hand side of the "U" tube when the trigger is pulled. English (1942) reports that in trials, the recruits concentrated on watching the target rather than looking at the "U" tube. An instructor informed the recruit of any changes in fluid level. English (1942) states that in

Like the quintain, English's teaching machine accepts input, performs a transformation of it, and then provides some instructive feedback almost immediately after the input. English's teaching machine appears to be successful in teaching a particular motor skill. English (1942) states,

> Men given up as hopeless by their officers and non-commissioned officers showed rapid improvement in a large percentage of cases ... Nearly all, after about seven hours drill in the laboratory, were brought up to the minimum standards for efficiency in actual range tests–much to the astonishment of the small arms instructors of their regiment. (p. 4)

Not all recruits were able to learn from this device, however. English (1942) states that the teaching machine did not work for individuals who had, "physiological incapacities, intention tremors, incorrigible unsteadiness, and low intelligence" (p. 4).

Despite the demonstrated success of this teaching machine, it was not adopted by the United States Army. The specific reasons for its rejection are not revealed, but it seems likely that the perceived need for that teaching machine was not sustained. Rather than gaining more personnel, the United States Army began to reduce its ranks after the end of the First World War. There would be little need for a teaching machine designed to train large numbers of recruits, therefore. As well, to use this type of teaching machine, many rifles would have to be modified, an expense which was probably not justifiable at a time when the army was being diminished. While it may be argued that the need for English's teaching machine was again present in the United States Army by 1942, because of that country's entry into the Second World War, changes in technology made such teaching machines obsolete. The rifles used in the First World War could only fire a few rounds a minute, since each round had to be loaded into the gun's breech manually. This feature meant that every shot should count whenever possible, hence one of the needs for extensive training in marksmanship. The advent of hand-held, rapid-fire guns, reduced the need for such exacting standards of marksmanship. When training in gunnery and marksmanship was deemed necessary, the United States Army tended to use mechanical and electrical simulators that could reproduce, in a controlled manner, many elements of an actual condition of use (Gagné, 1954).

While other teaching machines have been developed in the twentieth century for other aspects of military training, the field of scholastic education has experienced the greatest development and application of teaching machines in this century.

Pressey's prototype teaching machines

Sidney Pressey (1888-1979) was a psychologist who worked at Ohio State University for most of his academic career. His interest in instructional devices appears to be based on a perceived need of alleviating the problem of classroom teachers spending too much time supervising mechanical tasks such as drill. Pressey (1926) states,

> The average teacher is woefully burdened by such routine of drill and information fixing. It would seem highly desirable to lift from her shoulders as much as possible of this burden and make her freer for those inspirational and thought-stimulating activities which are, presumably, the real function of the teacher. (p. 374)

It seems that Pressey was concerned initially with designing machines that could administer and score particular tests automatically, thereby saving time and reducing the likelihood of examiner error (Pressey, 1926). It has been mentioned in previous chapters that many educators, beginning in ancient times, maintain that a device designed to although he likely came upon it without the knowledge of earlier endeavors. Pressey (1950) states, "Devices or special materials which at once inform a student about the correctness of his answer to a question, and then lead him to the right answer clearly do more than test him; *they teach him*" (p. 418).

As part of his doctoral research on the psychological effects of different colours, carried out at Harvard University between 1915-17, Pressey constructed a mechanical device using telegraph keys, sounders and an assembly of brass cog wheels altered to function as rotating contacts, to assist with the collection of data from subjects (Pressey, 1921). His interest in creating mechanical contrivances to collect information from human beings continued beyond his doctoral research.

Pressey began to design and to construct experimental instructional devices in the early 1920s. In 1922, he completed the first prototype machine that worked in a satisfactory manner (Pressey, 1926; Pressey, 1950). The machine was designed to be set up by the instructor to function either as a testing machine or as a teaching machine. A similar prototype was submitted for patenting in January 1926 (United States Patent Number 1,670,480, May 22, 1928). Figure 52 (after drawing in United States Patent Number 1,670,480, May 22, 1928) shows the external appearance of Pressey's prototype machine of 1926.

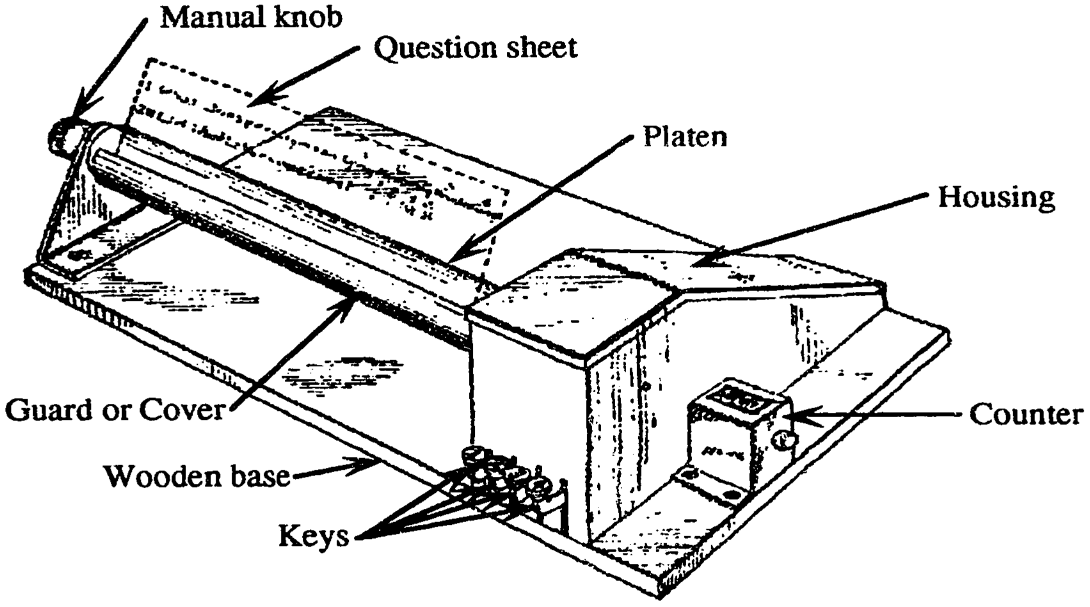


Figure 52. External appearance of Pressey's machine of 1926

The prototype machine constructed in 1922, which Pressey first exhibited in 1924, has been preserved in the Smithsonian Institution. Its appearance differs slightly from the device pictured in Figure 52. In the preserved model, the top of the housing is covered by a piece of wood. An additional guard or plate is located above the platen so that only one question is visible. As well, the preserved model also contains an attachment located to the left of the housing. This part is designed to release a single piece of candy down a chute when a designated number of questions are answered correctly. Pressey (1926) notes that he improved his first model of teaching machine between 1924 and 1925. The model depicted in Figure 52, does not possess either a candy dispenser or an additional guard. It is not clear, therefore, whether the device depicted in Figure 52 represents the providing the user with a *consumable* reward.

Few skills are required of a student to use this type of device. An instructor sets the internal mechanism and installs and aligns a multiple-choice question sheet on the platen. The student responds to each question by pressing the key that he/she believes represents the correct response. The machine may be set to function in one of two modes. In the *testing mode*, pressing any key will cause the machine to move the platen so that the next question is displayed. The counter is also advanced for every correct response. If the student selects the wrong answer, however, the counter is not advanced. In the *teaching mode*, the platen will not advance until the correct key is depressed. The counter records all key presses, both right and wrong. Power for the mechanism and the counter come from the mechanical action of the key presses (Pressey, 1926). Pressey (1926) envisaged a similar model powered by electricity. There is no evidence to show that such a device was produced by Pressey.

Preparation and internal operation

The internal workings of Pressey's first design of testing/teaching machine are considerably more complex than the external operation. Before the machine can be used by a student, the instructor must set the mechanism. Figure 53 (after drawings in United States Patent Number 1,670,480, May 22, 1928) is an overhead view of the mechanism as seen through the top of the housing. The drum is also shown in quarter-section.

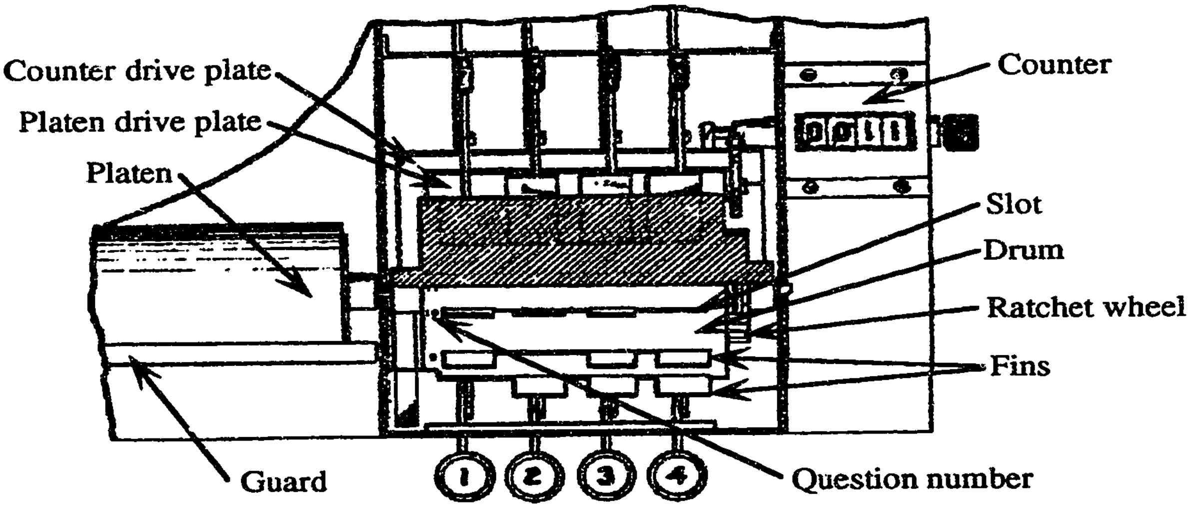


Figure 53. Overhead view of internal mechanism in Pressey's machine of 1926

To function correctly, the instructor must first adjust the fins in each slot so that a blank slot position corresponds to the key representing the correct answer for the question concerned. Each slot is numbered. The numbers are intended to correspond to the question numbers on the test sheets that are placed in the platen. While the fins in this model are shown to be rectangles of sheet metal that fit into the slots, the fins in the earlier prototype are smaller, hinged metal tabs, arranged so that they can be swung inwards or outwards from the drum (Pressey, 1926). The projecting fins represent incorrect choices, while the absence of a fin represents the correct answer. The instructor must turn the choose the operating mode of the machine. Figure 54 (after drawing in United States Patent Number 1,670,480, May 22, 1928) is a cross-sectional view through the right-hand end of the housing of Pressey's 1926 version of his testing/teaching machine, showing the selector arm placed so that the device will function in *teaching mode.*

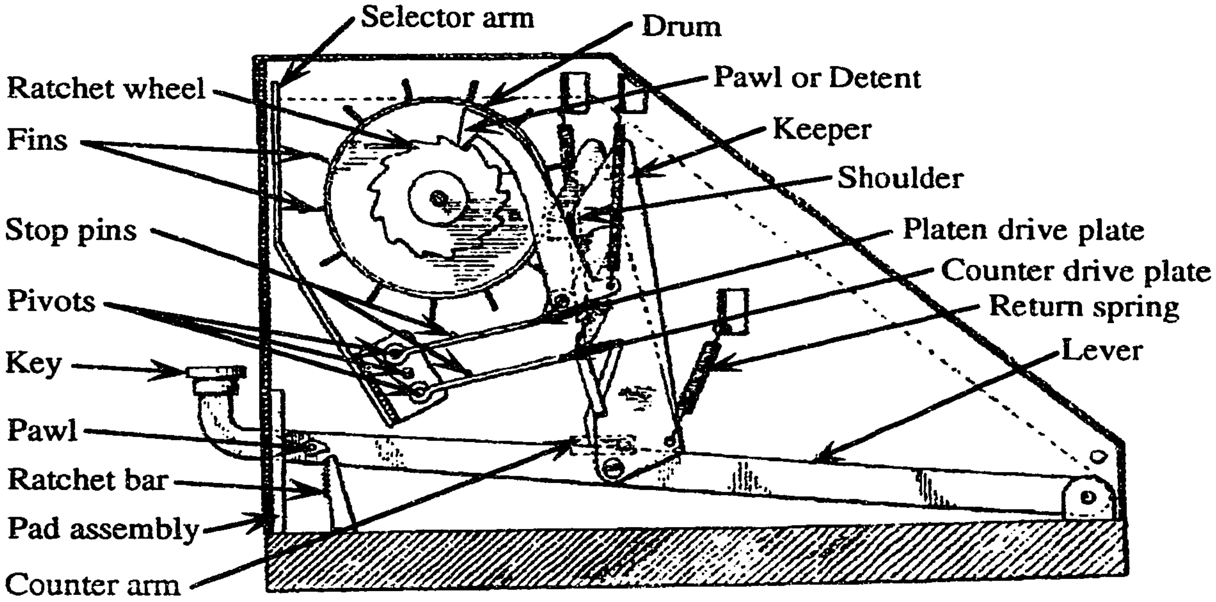


Figure 54. Cross-sectional view of Pressey's machine of 1926 in teaching mode

It is possible to provide a clear explanation of the operation of the internal mechanism with the aid of Figure 54. The pad assembly is designed to prevent more than one key from being pressed at once. If a key is pressed, the thickness of its lever pushes the adjacent pads apart. This action causes the other pads in the assembly to be forced together tightly, preventing any other key from being depressed at the same time. A pawl on each lever and a corresponding ratchet bar prevent the student from depressing keys part way to see which one will advance the platen. When a key is pressed by a student, a number of mechanical actions occur simultaneously. The pawl on the lever engages the ratchet bar, preventing the selected key from returning to its rest position until it is pressed down fully. The action of pressing the key also causes the keeper attached to the lever to move downwards. If the shoulder of the keeper is resting against a fin, then only the lower-most notch in the keeper engages a drive plate. In this particular instance, the keeper will depress the counter drive plate which, in turn, moves the counter arm so that the number displayed will be increased by one. A return spring pulls both the lever and the keeper back into position once the student has pushed the key down as far as it will go and then releases it. In the case of a key representing the correct answer, the shoulder of that keeper will be resting against the drum. In this position, a keeper will engage both the counter drive and the platen drive plates. When the key connected to a keeper in this position is pressed, both plates are moved downward. The platen drive plate will cause the large detent or pawl to pull against the ratchet wheel. This action results in the platen being advanced by one increment, which caused the next question to become visible if the questions have been placed on the paper in the proper manner. The movement of the counter drive plate will advance the number displayed by the counter by one.

and the platen drive plates. Figure 55 (after drawing in United States Patent Number 1,670,480, May 22, 1928) is a cross-sectional view through the right-hand side of the housing, of Pressey's 1926 version of his testing/teaching machine, in *testing mode*.

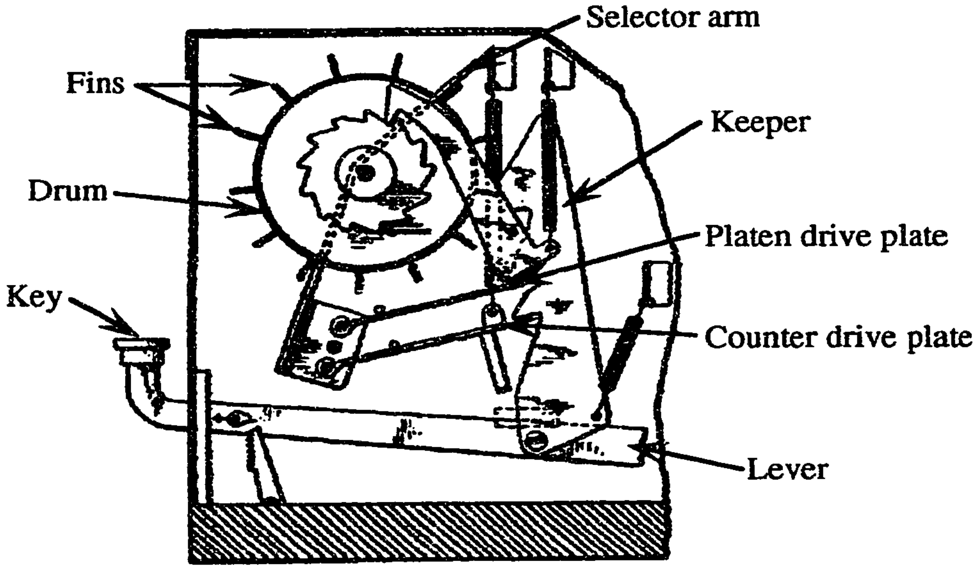


Figure 55. Cross-sectional view of Pressey's machine of 1926 in testing mode

When set to function as a testing machine, each key press will result in an incremental advance of the platen. This occurs because of the position of the platen drive plate. The number displayed by the counter is increased only when the correct key is pressed. In this instance, the shoulder of the keeper will be resting on the drum, and this position permits the counter drive plate to be engaged. Pressey (1926) notes that the machine may be used with true/false type tests by using only one fin in each row of slots.

There are a number of mechanical limitations inherent in this type of machine. Although Pressey made an effort to prevent a user from obtaining information about which key was correct by comparing the resistance of each key to being depressed, it seems that the pawl and ratchet bar did not prevent this feedback altogether (United States Patent Number 1,749,226, March 4, 1930). The machine is restricted to a maximum of 13 questions, equivalent to the number of slots in the circumference of the drum. Much preparation time is required to use this device either as a teaching machine or as a testing machine. The fins must be set for each question, an operation that may consume considerable time if more than one machine is to be used. Pressey (1926) for example, states that the use of 35 such machines in a classroom would save much of the time required for scoring quizzes. While time spent on grading would be saved if many classes took the same quiz, little or no time would be saved if only one or two classes took the quiz. It is also necessary to prepare the question sheets precisely, so that a new question will be visible with each rotational increment of the platen. As well, the question sheet must be attached to the platen so that each question is aligned with the proper slot on the drum. The provision of a manual knob with the platen (see Figure 52), enables students to move the machine past difficult questions without having to answer them. While the mechanism can count the total number of responses or the total number of correct responses, there is no method of indicating which questions were answered incorrectly. Bearing these mechanical limitations in mind, Pressey designed other models that were intended

Relationship to theories of learning

While it is stated previously that Pressey designed his testing/teaching machines because of perceived needs, they also seem to function in congruence with particular theories of learning. It appears that Thorndike's so-called *laws of learning* (see Chapter V) comprise the major theoretical basis of Pressey's devices (Pressey, 1926; 1927). It is not clear, however, whether Pressey designed his initial devices according to these *laws of learning*, or whether the completed apparatus just happened to reflect them. Pressey (1926) states, "The somewhat astounding way in which the functioning of the apparatus seems to fit in with the so-called 'laws of learning' deserves mention" (p. 375). Pressey was able to relate aspects of the machines' operation to specific laws of learning, nevertheless. The principle of the *law of recency*, for example, is embodied in the *teaching mode*, according to Pressey (1926), "since it is always the *last* answer [selected by the student] which is the right one" (p. 375).

While the first testing/teaching machines that Pressey produced may not have been designed from a basis of Thorndike's *laws of learning*, there is evidence to show that subsequent models were.

Pressey's teaching machine of 1927

Pressey was aware of many of the limitations of his first model machines. Besides technical limitations, Pressey (1926) notes that the design of the apparatus might result in "excessive overlearning", since students who repeat a sequence to redo questions that were answered incorrectly, will be subjected to the questions that were answered correctly as well. The second model that Pressey produced was intended to function solely as a teaching machine, but it was also designed to eliminate from subsequent view, questions answered correctly (Pressey, 1927).

The external appearance of the new model is similar to that of the earlier prototypes. Instead of a typewriter-like platen, the new model contains a cylinder that enables the question sheet to be clipped to it. This assembly is enclosed by sheet metal guards which permit one question at a time to be visible to the user. The shape of the mechanism housing is somewhat different than the first versions. As well, a shaft protrudes a distance from the right-hand side of the housing. The shaft is intended to be connected to a power source such as a falling weight or a clockwork mechanism (Pressey, 1927).

The internal workings of the 1927 model are markedly different from the versions of the first model. While the first model relies on the force of pressing the keys to rotate the platen, the new model relies upon an external power source to do this. In use, Pressey (1927) attached a weight by means of a length of string to the shaft protruding from the housing. A hinged latch or escapement holds the mechanism stationary most of the time. Like the first model, the questions are represented by slots across the circumference of a drum, but the capacity as well as the method of indicating the correct responses are different. A maximum of 30 questions can be accommodated by the new model. Fins are not used to designate incorrect answers. Instead, toothed racks or bars are used to interact with the remainder of the mechanism. The racks are held in the slots by means of guides or holders that permit the racks to be moved laterally along the slot by other parts of the mechanism (Pressey, 1927). The teeth of the racks resemble those of a handsaw. Unlike handsaw teeth, the teeth on the racks are not all arranged in the same direction. Figure 56 (after drawing and description in Pressey, 1927, pp. 550-551) shows the appearance of one type of toothed rack used in Pressey's teaching machine model of 1927.

It should be noted from Figure 56, that the angled portion of most of the teeth will cause the rack to move towards the right if an object is placed along the angled portion and an upwards force applied. The teeth are reversed in the "B" section. The teeth in this

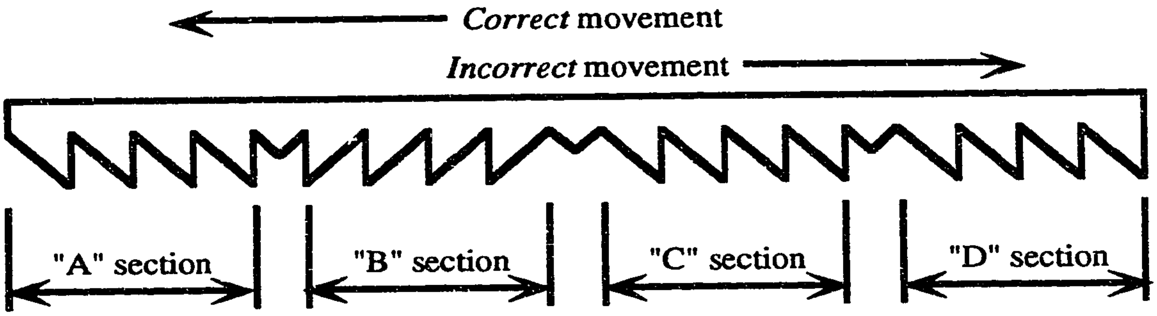


Figure 56. Example of a rack from Pressey's teaching machine of 1927

tion of the keys of this machine are similar to those of the earlier models, the internal operation is different. Instead of pushing levers downwards, as in the earlier machines, the levers on the new model are pivoted so that the ends opposite the keys are raised while the keys are depressed. The end of the lever that rises is shaped to a point so that it will fit in between the teeth on the racks. Depending upon the key pressed and the particular rack used, the key press will either move the rack to the right or to the left.

Before the apparatus may be used by a student, the instructor must place appropriate racks into the number of slots corresponding to the number of questions used. An additional feature of the device is that the hinged catch may be positioned laterally so that once a question is answered correctly a set number of times, it may be omitted from further display until the machine is reset. Pressey (1927) notes that because of the number of teeth in each *correct* section of the racks, the machine may be set to stop displaying questions after they are answered correctly either two, three or four times.

Once the racks and motive power are set, the student may answer the questions displayed by the machine by pressing a key. The movement of the key causes the pointed end of the lever to push against a tooth in the rack. If the student presses a key that represents an incorrect answer, the rack will be moved one increment to the right, since all teeth in *incorrect* sections face in the same direction (see Figure 56). Movement of the rack to the right does not permit the escapement to release the drum, so the same question continues to be displayed. A key press that does not result in a new question being displayed, indicates to the student that an incorrect response was selected. The student must select another key. When the correct key is pressed, the rack will move one increment to the left. This action permits a spring-loaded arm on the lever to release the hinged catch. This action allows the drum to rotate to the next rack, where the hinged catch will engage and stop the drum's movement. This process continues for the remainder of the questions. If the racks are set to drop questions when they have been answered correctly twice in a row, for example, the second time around, the movement of the rack to the left will align one of the spaces between sections of the teeth with the hinged catch (see Figure 56). This arrangement means that the hinged catch will not stop the rotation of the drum until a rack is encountered that is not properly aligned. In other words, the apparatus will stop when it encounters a question that has not been answered correctly twice in a row.

When all of the questions have been answered correctly the required number of times, the new position of all the racks engage a system of levers that causes the hinged catch to stop the drum from rotating. Before the drum is stopped, this same system causes a ticket or a coupon to be ejected from a slot in the housing, indicating to the student that the operation has been completed successfully (Pressey, 1927).

It is apparent from the previous discussion that Pressey addressed some of the mechanical limitations of his first model machines. While he succeeded in alleviating some cient for some purposes. The nature of the internal mechanism probably eliminates the possibility of a student discerning the correct response by comparing the resistance of each key to being pressed. A fully enclosed platen with clips to hold the question sheet reduces the problem of aligning the sheet with the question slots on the drum. The absence of a manual knob on the platen, probably reduces the likelihood that a student will sabotage the machine by misaligning the question sheet and the drum.

The time required to prepare the apparatus does not seem to be improved upon. While racks can be inserted into the slots quickly, care must be taken to select the correct type of rack for each question. It is also likely that students could defeat the proper operation of Pressey's 1927 model teaching machine by never pressing the correct key. If an incorrect key is pressed more than three times, then one of the spaces in the rack will be aligned with the hinged catch, thus permitting the drum to move to the next question. In most instances, including pressing the correct key because it is the only choice left, no more than three wrong key presses in a row are possible. If the student, either by design or through ignorance, presses incorrect keys four times, then the machine will probably display the next question, even though the correct answer was not selected.

While Pressey (1927) acknowledges that his 1927 model teaching machine was not perfected mechanically, his greater concern was with the underlying learning theories embodied as well as the pedagogical principles employed.

Relationship to theories of learning

Echoing Thorndike's concern about *overlearning* (see Chapter V) Pressey (1926) states that a machine that omits questions after they are answered correctly will not only prevent overlearning, but omitting such questions will concentrate the user's attention on those questions that have been answered incorrectly. Pressey (1927) states that the 1927 model, like the previous model, is congruent with the *law of recency*, since it is the correct key press, representing the most recent response selected, that will cause the machine to advance to the next question. Thorndike's original *law of exercise* (see Chapter V) is considered in the 1927 model, since a correct answer must be selected a number of times before it is omitted from the sequence (Pressey, 1927). The validity of this position, as well as Thorndike's abandonment of it, are discussed in Chapter V. Pressey (1927) also expresses concern because the user is repeatedly exposed to incorrect information,

> it appears unfortunately possible that wrong associations may be developed as well as the correct 'bond'–though it might be argued that learning might involve not only the establishment of the right response but the avoidance of common wrong responses. (p. 552)

Pressey (1927) also indicates that one of his graduate students was undertaking a study to ascertain the efficacy of presenting wrong information along with correct information (p. 552). This study will be considered in a subsequent section.

The validity and the appropriateness of providing a tangible reward to users when a sequence has been completed successfully, is a concern that Pressey resolved by eliminating reward dispensers from subsequent models of his machines. Pressey (1926) indicates that the provision of a candy or a similar reward reflects Thorndike's *law of effect* which, it is maintained, will assist the user in *stamping-in* the correct response (see also Chapter V). While Pressey does mention the *law of effect* in subsequent works, the references are not to the provision of a tangible reward. As far as his 1927 model of teaching machine is concerned, Pressey (1927) states that the user of the machine,

> is penalized every time he makes a wrong answer by being required to answer the

> elimination of that question, the 'law of effect' is constantly operating to further the learning. (p. 552)

The purpose of the coupon being presented by the 1927 model teaching machine, is explained solely as an automatic indication that the end of the lesson has been reached (Pressey, 1927).

While mechanical problems and limitations probably discouraged Pressey from developing this type of teaching machine further, he designed a third model, based on the mechanical arrangement of the 1922 and 1926 versions, that was marketed commercially.

Pressey's 1928 model testing/teaching machine

Pressey's third type of device is intended to function like the first models, but with some of the mechanical improvements of the 1927 model. As well as being much smaller than the earlier models, the 1928 model uses the action of key presses to provide the energy necessary to operate the internal mechanism. Figure 57 (after drawings in United States Patent Number 1,749,226, March 4, 1930) shows the general external appearance of Pressey's testing/teaching machine model of 1928.

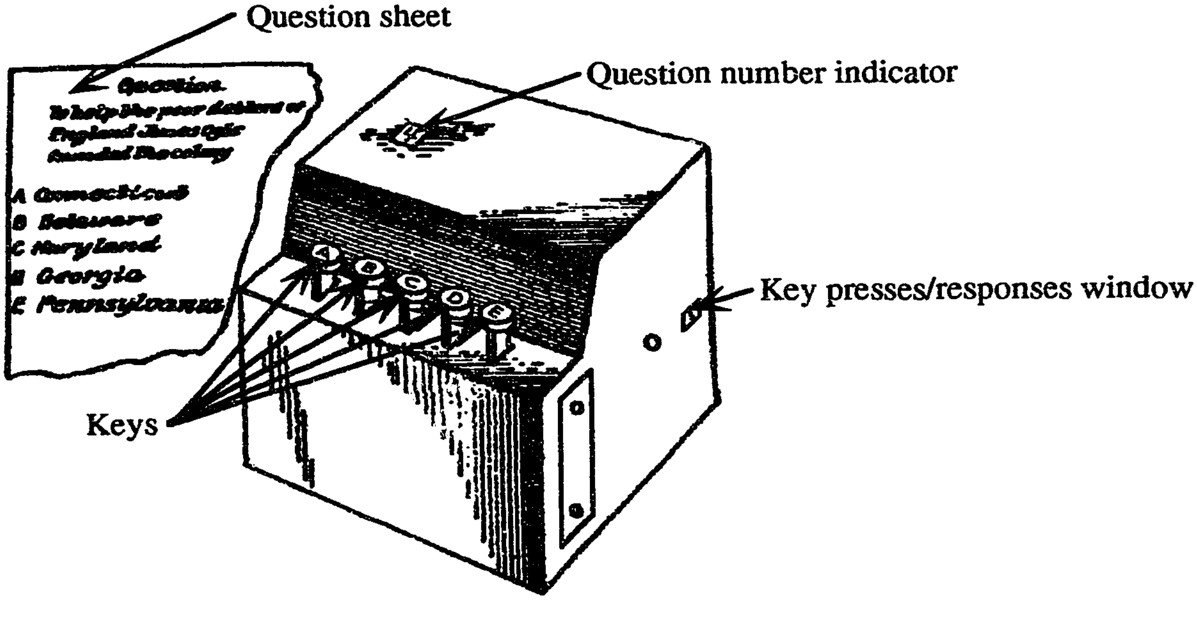


Figure 57. External appearance of Pressey's testing/teaching machine of 1928

The use of a platen to hold the question sheets and to display one question at a time, as found on the earlier models, was dispensed with. The removal of this feature also eliminated two potential problems. One, special layout of the answer sheets, so that each question would be properly aligned with each movement of the platen, was no longer required. Different formats of question sheets could now be used. Two, it was no longer necessary to align the answer sheet and platen with the internal mechanism of the device, so time required to prepare the apparatus was reduced.

Although Pressey does not state so, the 1928 model is easier to use by left-handed gether, it is possible for a left-handed person to place the machine to the left of the question sheet and to press the keys with the fingers of the left hand. It seems likely that this ergonomic consideration did not occur to Pressey, since another feature of the 1928 model is an opening on the right-hand side of the machine (see Figure 57) that displays either the total number of key presses or the number of questions answered correctly to that point, depending upon how the machine is prepared. The opening is placed to enable a teacher or supervisor to monitor the progress of each student without disturbing them unduly (United States Patent Number 1,749,226, March 4, 1930). It is likely that an instructor would not have a clear view of the window if the student was operating the device with his/her left hand.

The 1928 model permits greater flexibility in exam design over earlier models by the inclusion of an additional key, so that up to five answer choices are possible for each question (see Figure 57). The design of the housing and internal components facilitates mass production, since most of the parts may be either stamped or cast (United States Patent Number 1,749,226, March 4, 1930). Another feature of the 1928 model is a large capacity drum that does not use either fins or racks. Instead, the drum is designed to hold a special punched sheet, the perforations representing the correct responses to each question. The sheet may be made of some flexible material such as heavy paper or cardboard (United States Patent Number 1,749,226, March 4, 1930). The maximum number of questions that can be accommodated by this machine is 100. Figure 58 (after United States Patent Number 1,749,226, March 4, 1930) shows an overhead view of the interior of Pressey's 1928 model machine. It should be noted that the keys and some other parts are omitted for clarity.

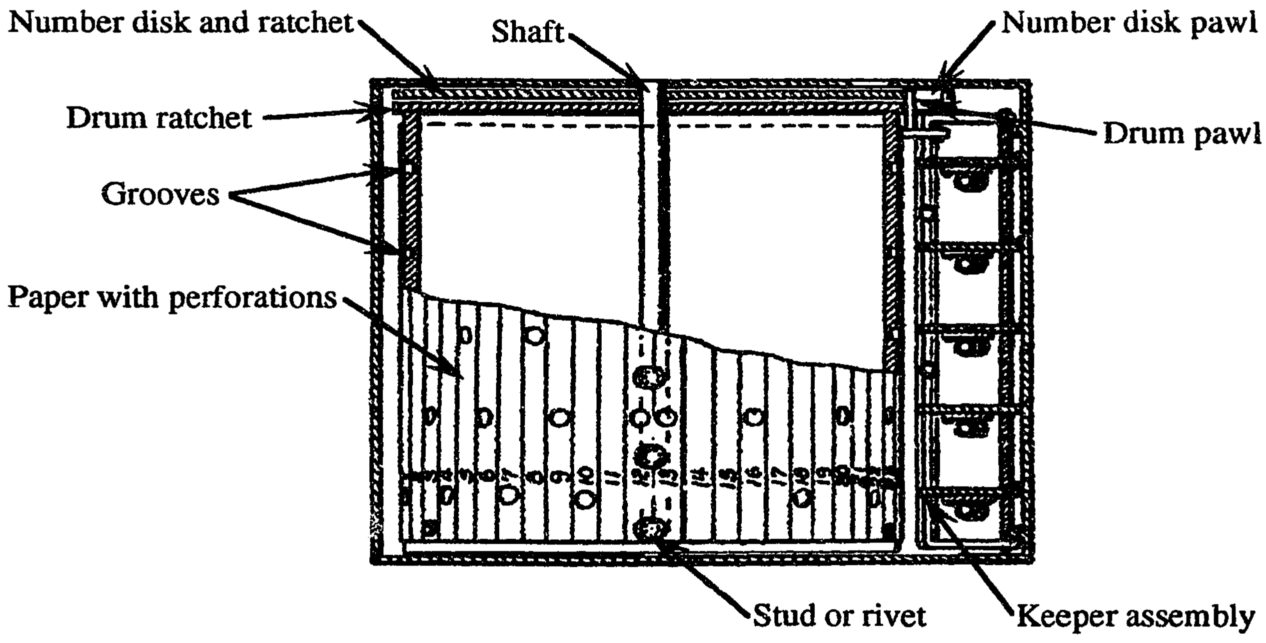


Figure 58. Overhead view of interior of Pressey's model of 1928

The perforated sheet is hooked onto a series of studs or rivets (see Figure 58) which hold the sheet in position. Numbers either written or typed near the left-hand edge are intended to be viewed by the student through the opening in the top of the housing (see Figure 57). The numbers also facilitate the correct placement of holes in the sheet.

tion and which overcome some of the mechanical problems encountered with previous models. Unlike the earlier devices, the mechanism of the 1928 model is not activated when a key is pressed. Instead, the mechanism is actuated by the motion of the key returning to its rest position (United States Patent Number 1,749,226, March 4, 1930). Figure 59 (after drawing in United States Patent Number 1,749,226, March 4, 1930) shows cross-sectional view through the left-hand side of Pressey's machine of 1928.

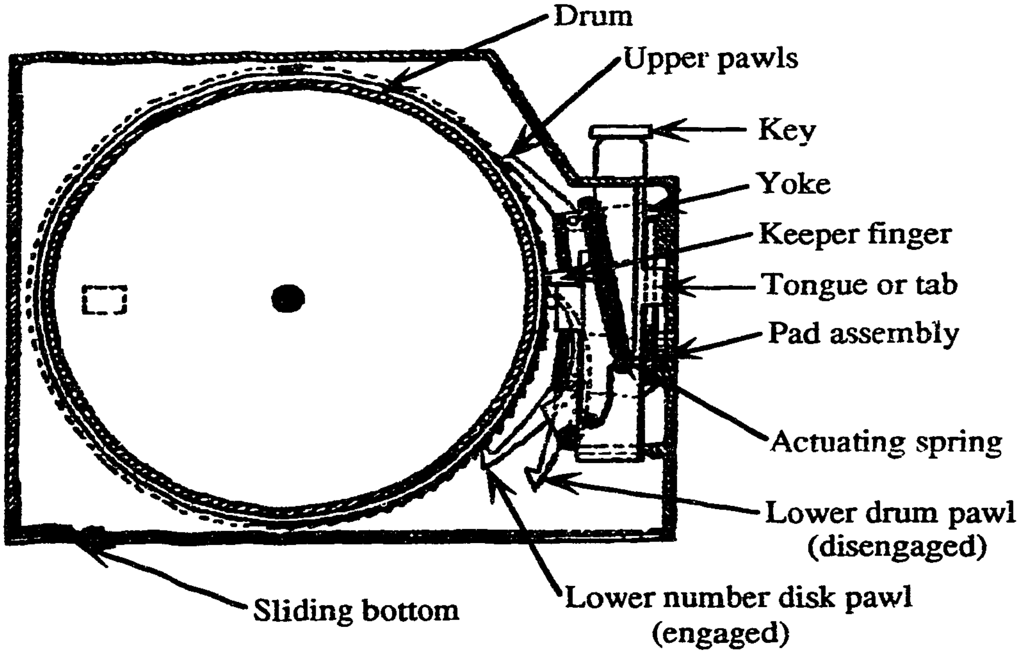


Figure 59. Cross-sectional view through Pressey's machine of 1928

As with all previous models, it is intended that the user make responses to questions by pressing one of the keys. Like the 1922 and 1926 versions, the 1928 model is equipped with a system of pads to prevent more than one key from being depressed at a time. Instead of the pads acting upon levers, a square tongue or tab, formed as a part of each key plate, passes through the pad assembly (see Figure 59). Once a tab enters the pad assembly, there is insufficient room for another tab to enter. In this way, only one key may be depressed at a time. A system of pawls and ratchets hold both the drum and the number disk in a given position and also cause these parts to move. The action of a key being pressed permits a keeper connected to the key to move towards the drum. A finger on the leading edge of the keeper will either strike the sheet on the drum, or the finger will pass through a hole in the sheet, coming to rest in one of the grooves of the drum. If the finger of the keeper passes through a hole, this movement permits the yoke holding the upper pawls to pivot downwards. This action moves both of the upper pawls down by one tooth increment, when the key is pressed down completely. No action occurs with the drum or number disk until the key is released. In this particular instance, releasing the key will cause the actuating spring to pull the key and keeper upwards to their rest position. The upwards movement of the key will also cause the two upper pawls to advance both the drum and the number disk by one increment. By designing the apparatus so that the drum is moved only on the return stroke, Pressey maintains that the user will not gather any instructive feedback from partially depressing each key in series to see which one will cause the drum to move. This design is considered to be superior to the pawl and ratchet bar assemblies used on earlier models (United States Patent Number 1,749,226, March 4, 1930).

If a key representing an incorrect response is pressed, the finger of the keeper will not encounter a hole in the sheet. The keeper will not permit the yoke to pivot downwards. The upper pawls will not move either the drum or the number disk. In such instances, movement of the drum or the number disk is dependent upon the positioning of the two lower pawls. When preparing the machine for use, the instructor may engage either one of the two lower pawls. The functioning of the machine is determined by which pawl is engaged. If the lower pawl controlling the number disk is engaged, then each press of a key representing an incorrect response results in the number disk being moved by one increment. The drum will not move until the key representing the correct response is pressed and then released. In this mode, the device functions as a teaching machine. The failure of the drum to move indicates that the wrong response was selected.

If the lower pawl controlling the drum is engaged, then each press of a key, whether it represents a correct or an incorrect response, results in the drum being advanced by one increment. The number disk will advance only when the key representing the correct response is depressed. Prepared in this manner, the device functions as a testing machine (United States Patent Number 1,749,226, March 4, 1930).

A version of the 1928 model machine was manufactured and marketed by the Welch Scientific Company of Chicago, Illinois (now part of Sargent-Welch Scientific Company) beginning in 1930. The appearance of this version is similar to that shown in Figure 57. The housing of the Welch version is rounded on the top, however, and the keys are different. Each key is also designated by a numeral stamped into the top, rather than by a letter (photograph in National Council of Teachers of Mathematics, 1973, p. 138). Although the machine may function in both testing and teaching modes, it was marketed as the *Pressey Testing Machine*, suggesting that Welch considered the testing feature of the machine to be more saleable than the teaching capability. The machine did not remain in production long, primarily because of prevailing economic conditions. Pressey (1964a) states that during the Great Depression, "there were no funds for innovations (the writer financed most of his apparatus-building out of his own pocket), and, with thousands of teachers unemployed, any possibility of creating technological unemployment was to be avoided" (p. 357). It is likely that manufacture of the Pressey Testing Machine was discontinued by 1932. Describing his commercial venture later, Pressey (1967) notes that by the time the effects of the Great Depression were widespread, "The manufacturer of one crude teaching machine I had been able to get on the market withdrew it from sale" (p. 323).

While the Sargent-Welch company does not possess records of how many machines were produced or sold (personal correspondence with R. L. Bieser, Vice President, May 10, 1989) there is evidence to indicate that several machines were manufactured and sold. One of Pressey's doctoral students at the time, J. K. Little, reports that up to 60 units were used in experiments with classes. Little also states that he is unaware that any of Pressey's machines were used in an elementary or a secondary school (personal correspondence with Dr. J. K. Little, December 29, 1988). Pressey (1964a) states that he and others note that a basic reason why his devices failed commercially is that, "the educational world was not yet ready for any such innovation" (also Skinner, 1958). The preceding quote is vague, since there are at least two possible interpretations of why educators did not accept Pressey's devices. Many educators who taught small classes might not share Pressey's perceived need of a more efficient method of test administration. The teaching feature of these devices, dependent upon them being used as teaching machines, might appear to be superfluous, therefore. It is also likely that most educators were unconcerned of the importance of reliability in measurement because classical test theory had yet to be developed. There is a lack of evidence to indicate that educators who were aware of Pressey's devices rejected their use because they considered them incompatible with popular practices of the time.

of the final examination, students in both groups were required to answer both essay-type as well as multiple-choice portions (Little, 1934).

The results indicate that the scores of the groups using the testing or drill machines were generally somewhat higher than the scores of the control groups (Little, 1934). The experimental groups also obtained higher scores on the essay-type questions. Variability in the grading of essay-type questions is cited as the probable explanation for this difference in scores between groups. Little (1934) also attempted to ascertain whether students using the testing or drill machines obtained higher scores on subsequent trials of the same examination. While the scores increased gradually, Little (1934) notes that, "Students missed items on the second and third trials which they answered correctly on the first" (p. 48). This observation may raise the question about the efficacy of this method, since it appears that some information is either not learned or is forgotten. Little (1934) explains these observations by stating, "The results are an interesting suggestion as to the probable slow and 'developmental' character of learning" (p. 48). Nothing further is mentioned about this matter and no comparison is made between what was observed and Thorndike's *laws of learning*.

Although the individual scores between groups did not differ widely, Little (1934) concludes that students do learn from the machines and that they do have a practical use in the classroom. Although Pressey (1932) indicated that he was discontinuing work on his teaching machines, his interest in them remained and he again tried to promote their use during the Second World War.

Later developments of Pressey's teaching machines

At the entry of the United States in the Second World War, Pressey perceived the need that the United States armed forces might require efficient mass-training strategies; his teaching machines might be useful for such mass-training (Pressey, 1967). Although Pressey informed the United States Navy Office of Research and Invention of his teaching machines, the Navy was not interested when they learned that they were not in production (Pressey, 1967).

In a presentation given at a conference of the American Psychological Association, Pressey (1946) indicates that he was resurrecting his earlier teaching machines. This renewed interest in promoting his devices was probably the result of a new perceived need for them. This need was the training of military veterans returning from service in the Second World War (Pressey, 1947). Pressey (1947) also notes that his testing/teaching machines should be upgraded mechanically to improve their operation.

Unlike his earlier efforts, which were funded largely by Pressey himself (Pressey, 1964a), the cost of developing a modern version of his 1928 model testing/teaching machine was underwritten by a grant from the Special Devices Center of the Office of Naval Research (Mead, 1949; Pressey, 1967). It is likely that several working examples of the new version testing/teaching machine were fabricated, since Mead (1949) reports that the purpose of the project is "the procurement of production models" (p. 100) described as "small automatic drum tutor[s]" (p. 98). The contract for manufacture was awarded to the Brandywine Precision Manufacturing Company (Mead, 1949). There is no indication that any examples were made available for commercial sale. It is likely that the production models for the Special Devices Center were completed by 1950, since a number of them were used in a study, completed in 1953, by one of Pressey's doctoral students (Stephens, 1953).

The external appearance of the improved model, referred to as a *drum tutor* by Stephens (1953) is similar to the 1928 model shown in Figure 57, except that the newer model possesses four keys, not five, and the error count window is positioned on top of the housing rather than on the right-hand side (photograph in Skinner, 1958, p. 970). Pressey (1950) indicates that the reason for reverting to four keys, is that most multiple-choice questions do not have five plausible distractors. Pressey (1950) states,

> Where the most important function served by a test is instructional, each alternative answer should make a real contribution to instruction... No alternative answer [distractor] should confuse the student or introduce ways of construing the question which are not educationally profitable to consider. (p. 422)

While Pressey does not indicate why the error-count window was moved to the top of the housing of the drum tutor, it is likely that he considered the information provided in the window, the total number of errors made, to be useful feedback for the user. Stephens (1953) supports this view. He states, "each individual knows immediately whether each response is right or wrong and has before him a cumulative count of his errors" (p. 505).

The principle of operation of the 1950 model testing/teaching machine appears to be identical to that of the 1928 model, although descriptions vary. Stolurow (1961) claims that every time an incorrect key is pressed, a bell rings as an audible indicator that an error has been made. It is most likely that Stolurow's statement is incorrect, since Stephens (1953) makes no mention of such feedback. Stephens (1953) states that when an incorrect key is pressed, "the error count increases by one and the item window remains the same; this indicates that he [the student] is to try again" (p. 505). As well, the inclusion of an audible signal, while possibly alerting the user that an error has been made, would probably be distracting and confusing if several machines are used simultaneously.

While Pressey desired to have his new model testing/teaching machine used by the Navy and, perhaps marketed commercially as well, there is no indication that the Navy found the device to be appropriate or viable (Pressey, 1967). It is important to note that while the 1950 version of the testing/teaching machine was being evaluated, other teaching machines of simpler and less expensive designs, some of them developed by Pressey, were also being evaluated. It is likely, therefore, that there was no further development of the 1950 device once the project for the Special Devices Center was completed. In subsequent writing, Pressey does not refer to the 1950 testing/teaching machine except in an oblique manner. For example, Pressey (1964a) states that he describes the features of his earlier teaching machines, "because they illustrate possibilities in automation which have since been neglected but which are of likely value" (p. 356). Although Pressey was approached by B. F. Skinner in the late 1950s, when his teaching machines were becoming popular, Pressey (1964a) indicates that he did not develop his devices further.

Relationship to theories of learning

As a part of his doctoral research, Stephens (1953) compared attributes of the 1950 *drum tutor* with those of another type of teaching machine that will be described in a subsequent section. The study also investigated any relationships between the operation of the devices and Thorndike's *law of effect* (Stephens, 1953). It is likely, therefore, that some of Thorndike's theories of learning continued to underlie the design of Pressey's teaching machines.

Stephens (1953) discovered that students obtained higher scores on examinations when they used the *drum tutor* in teaching mode, which does not allow a student to proceed to the next question until the one being worked on is answered correctly. It was also discovered that students' scores were lower when they were allowed to proceed through the examination without any indication of which questions were answered incorrectly, and were then required to repeat those questions answered incorrectly initially. This latter method of testing, referred to as *vanishing* by Stephens (1953) is said to be similar to a method used by Thorndike. From the data gathered, Stephens (1953) contests Thorndike's (1932) finding that a student will repeat a mistake when that question is presented subsequently, even if the student is informed of the *wrongness* of a response immediately after it is made. While Stephens' (1953) findings may refute Thorndike's (1932) theory, it seems that the findings support one of Thorndike's earlier positions.

Thorndike (1912) states, in the case of books, that one should not be allowed to proceed until the operation being worked on is completed successfully. It is also possible to apply this principle to examination questions in the manner that Pressey's testing/teaching machines do when set in teaching mode. While Stephens (1953) does not address the confusion surrounding Thorndike's many theories, it is clear that Pressey's teaching machines continued to reflect at least some of Thorndike's theories of learning.

There are indications that Pressey's position on how students learn and how teaching machines should be designed to incorporate these theories of learning was changing. In criticizing teaching machines constructed according to the principles of behaviorism, Pressey (1963) contends that learning in human beings does not consist simply of shaping behavior and reinforcing it. Citing findings from a study by Brownell (1928) Pressey (1963) states that,

> Simply telling them [students] that 2 x 3 = 6 did *not* bring about real learning of that number combination. These sturdy little empiricists had not merely to be *told;* they had to be *shown,* as by putting out two sets each of three pennies and demonstrating that they did indeed count to six. (p. 2)

Pressey (1963) also mentions the work of Piagét, stating that a student's concept of number systems is cognitive and develops gradually. At this juncture, Pressey's theories of learning appear to be congruent with the much older theories of Quintilian, Erasmus, Locke, Pestalozzi and Montessori. Pressey criticizes teaching machines embodying behavioristic theories of learning in another way which reveals more about how Pressey envisaged the use of his teaching machines.

Pressey (1962) notes that, "teaching machines of the past few years have attempted to replace textbooks and *initially* present what is to be learned" (p. 31). In sharp contrast, Pressey (1962) states that he never intended his machines to present the student with new information initially, "the student first looked over a reading assignment, laboratory exercise, or other material, and only *after* some such first contact with the matter to be learned did the auto-instructional procedure present carefully chosen questions on that matter" (p. 30). This position is congruent with the ways in which he deployed his testing/teaching machines in the past. Although Pressey (1950) states that his machines actually teach the student, either by correcting errors or by providing new information it is implicit in the design of his machines that they be used with students who are already familiar with the subject matter presented by the machine. Given that Pressey's testing/teaching machines reflect some of Thorndike's *laws of learning*, it is possible to assume that Pressey's machines may be used to teach someone ignorant of a given topic, since one aspect of Thorndike's theories of learning is sometimes referred to as *trial-and-error learning* (Lefrancois, 1982; Hergenhahn, 1988). While it is possible for a student who is ignorant of a particular topic to operate one of Pressey's teaching machines, it is doubtful, given what Pressey (1963) states, that the student gains more than an ability to answer the questions by means of rote. There is an assumption made with some ancient teaching machines as well as with teaching machines developed independently of Pressey, and before Skinner introduced his devices, that these varieties of teaching machines may be used to provide instruction once some initial instruction has been provided by other means.

Although Pressey criticizes behavioristic theories of learning, he does not condemn the use of teaching machines altogether. Pressey (1964a) maintains that teaching machines are useful in teaching concepts, including concepts of mathematics, "not as rote learnings but with an artfully formed series of 'number pictures' to develop number concepts. Drill in arithmetic or grammar may be so aided–not simply by reinforcings but by cognitive integrations and clarifications" (p. 368). By this time, however, Pressey had discontinued work on teaching machines, so he did not develop new models that embody these attributes.

Pressey's scoring and tabulating machine

One disadvantage of Pressey's testing/teaching machines is that the teacher is still required to tabulate the scores and errors of each student and perform item analyses if desired. Pressey (1932) basing his work on earlier efforts by others, designed a type of punched answer sheet that records a student's response to each question. The answer sheet, consisting of ordinary paper, is held between two interlocking metal plates, perforated with 30 rows of holes. Each row contains five holes, one hole for each possible response (Pressey, 1932). A maximum of 30 questions may be answered using this answer sheet. The student responds to each question by inserting a pencil tip or similar stylus through the hole corresponding to what is considered to be the correct response. The tip of the stylus punches a hole through the sheet. To facilitate grading and item analysis, Pressey (1932) designed a machine that could interpret the holes in the answer sheets. The scoring and tabulating machine consists of a wooden base which holds two metal rails that in turn hold a moveable carriage and an aluminum block containing a matrix of holes. Spring-loaded pins are placed in holes representing correct responses for the particular examination used.

In use, the teacher places each answer sheet onto the matrix block. Once in place, any pins corresponding to holes in the sheet will project through those holes. Pins located beneath portions of the answer sheet that are not punched, have insufficient strength to penetrate the paper. The carriage is then drawn across the matrix block. The rails guide the carriage and keep it aligned with the matrix block. Each pin projecting through the answer sheet strikes a counter mechanism connected to the carriage. By this method, the apparatus tabulates the score of each answer sheet. Depending upon how the scoring and tabulating machine is prepared, it may simply score each sheet, or it may also keep a cumulative record of the total number of students who answer each question correctly (Pressey, 1932).

It seems that Pressey did not attempt to have the tabulating and scoring machine produced commercially, although Little reports that he used five or six of them in his study (personal correspondence with Dr. J. K . Little, January 19, 1989). Little indicates further that the devices also contained a mechanism that printed the number of questions answered correctly on the back of each answer sheet (personal correspondence with Dr. J. K. Little, December 29, 1988). Although Pressey's tabulating and scoring machine is not a teaching machine, it is mentioned to show that Pressey was not developing his devices along the same lines as some others, whose work lead ultimately to the production of computers.

Although Pressey makes no indication of it, his tabulating and scoring machine operates in a similar manner to the tabulating machine patented by Herman Hollerith (1860-1929) in 1889 (United States Patent Number 395,783, January 8, 1889). Hollerith's firm, Computing-Tabulating-Recording Company, eventually evolved into the company now known as International Business Machines or IBM (Augarten, 1984). An important distinction between the two machines is that Hollerith's was electro-mechanical, while Pressey's was just mechanical. Pressey (1932) indicates that his apparatus may be modified to use electrical components such as photoelectric cells. There is no evidence that Pressey constructed or had constructed a tabulating and scoring machine that was electro-mechanical in operation. While it is not clear whether Pressey was influenced by Hollerith's work or not, it is clear that Pressey's work did not evolve towards the development or the use of computers. Moreover, while Pressey (1950) notes the existence of an IBM electric test scorer, which may have been operated by a simple computer, his articles from the 1960s do not mention the use of computers as teaching machines, although systems such as PLATO were in use at that time. In spite of his apparent neglect of computers, Pressey (1964a) states that he, "persists in the conviction that devices–often 'hardware'–should be and ultimately will be an integral and a major feature of 'autoinstruction'" (p. 369). By the 1950s, however, most of Pressey's efforts with teaching machines were directed toward the development and marketing of less mechanically-elaborate devices.

Petersons' testing/teaching machines

In his study with Pressey's 1928 model testing/teaching machine, Little (1934) notes that some of the devices failed in use and that some students were "annoyed" by noises that the machines made in use (p. 49). While Little (1934) does not indicate that mechanical failure, or the noise of the machines interfered with learning by the user, it is likely that this factor was a concern to others.

Concerned initially with ensuring uniform testing processes in experiments, a former graduate student of Pressey's, Hans Peterson and his brother John, designed two varieties of teaching machines that did not use elaborate mechanisms (Pressey, 1950).

Mechanical self-instructor and tester

In its original form, Peterson (1930) marked an envelope with rows and columns of circles. The circles represent possible selections to multiple-choice questions. Two specially prepared sheets, composed of paper stock somewhat thicker than that of the envelope, were placed inside the envelope. One sheet, inserted to be located next to the printed part of the envelope, is perforated with holes that correspond to the positions of the circles on the exterior of the envelope. The other sheet, placed beneath the perforated sheet, also contains perforations, but these occur only at locations that corresponded to a *correct* response (Peterson, 1930). This sheet comprises the answer key. Once the two perforated sheets are inserted into the envelope and the flap sealed, the assembly is given to the user.

In use, a response to a given question is selected, and the choice is registered on the envelope by punching the circle corresponding to what is contended to be the correct answer with a pencil or similar stylus. If the selection made is incorrect, then the stylus penetrates only the envelope and the corresponding hole in the perforated sheet. The thickness of the answer key sheet prevents all but the most determined thrusts from continuing. The resistance encountered indicates to the user that the answer selected is incorrect. If the user selects the correct response, however, then the stylus passes through the envelope, perforated sheet, answer sheet and possibly through the opposite side of the envelope. The larger hole produced, as well as the additional travel of the stylus, informs the user that the response selected is correct (Peterson, 1930).

By means of this simple apparatus, Peterson (1930) contends that a student not only obtains instructive feedback, but that the instructor is provided with a convenient means of scoring the examination. The device accepts student input, it transforms the input (allowing either a small or large hole to be produced) and it provides instructive feedback based on the input. While the feedback is general rather than specific, it is instructive to the user provided that the significance of the apparatus and the significance of the different sized holes are understood. Although it is not mentioned, this apparatus enables an instructor to ascertain which distractor, if any for any particular question, is most often selected by a class or a group.

The Petersons' self-instructor and tester appears to have several attributes that make it superior to Pressey's machines. These attributes include simplicity of design, apparent ease of use, and lower cost. While the Petersons' apparatus cannot tabulate scores itself, there appears to be a greater potential drawback to the apparatus. It is possible for a student to cheat, if the assembly is held so that light passes through the side of the envelope opposite the printed circles. If there is sufficient light, then the position of the holes in the answer sheet will be visible as a change in contrast on the surface of the envelope. While an instructor may be diligent in supervising an examination, it is not always possible to see what every student is doing at once. This type of cheating is practically eliminated by the other teaching machine invented by the Petersons.

Chemical self-instructor and tester

The Petersons designed another variety of their combination testing/teaching machine. This version consists of a piece of paper printed with circles in the manner of the envelope version. The paper is also printed with particular chemicals that normally appear invisible when dry. When another chemical in solution is brought into contact with these chemicals, usually by means of a pen, brush or swab, the chemicals on the paper become visible by changing colour (Peterson, 1930; 1931). This version is intended to be used in a manner similar to the mechanical self-instructor and tester.

Effectiveness and developments

Peterson (1930) notes that both versions of the self-instructor and tester can be used by students only if they are,

> sufficiently advanced mentally to find with reasonable ease and accuracy the point on the tester surface corresponding to each alternative answer to a question. This mental requirement corresponds roughly to the average intelligence of pupils in the fourth and fifth grade of the elementary schools. (p. 44)

Peterson (1930) does not cite any studies or findings to support his contention that younger students do not have the capability to use the self-instructor and tester successfully. While poor hand-eye coördination among some younger students may interfere with their successful use of the apparatus, there is evidence to show that many younger students are able to use instructional devices successfully. LaZerte's *primary number booklets* are mentioned in Chapter V. The booklets are intended for use with students in grades one through three (LaZerte, 1937). While not teaching machines, these teaching aids require more elaborate hand-eye coördination skill, such as printing in the correct location and movement of the sheet and question/answer page, than are required with the self-instructor and tester. While Peterson (1930) may be overly cautious about the effectiveness of his teaching machines with younger students, an important question is raised; to what extent do instructional devices, teaching machines in particular, add to the complexity of what is intended to be learned? While Peterson (1930) skirts this question by stating that the self-instructor and tester is simple to use, other educators who invented teaching machines investigate the question further. This matter will be discussed in subsequent sections and chapters.

Peterson (1931) performed several experiments to ascertain if there are any differences in achievement between students using the self-instructor and tester and students not using the device. Although the number of subjects in each group was low, ranging between 19 and 23, Peterson (1931) found that examination scores were higher among those groups using the self-instructor and tester devices. In one part of the experiment, a control group and an experimental group were switched, so that the old control group was provided with self-instructor and tester machines and the old experimental group had them taken away. Peterson (1931) found that the scores of the experimental group was always higher, even if the control group had the benefit of using the apparatus previously. He also concludes that the higher scores are attributable to the positive influence of the self-instructor and tester on learning. Although Peterson demonstrated that the self-instructor and tester appears to be an effective teaching machine, he did not attempt to explain the apparatus according to any learning theory. It is likely, given Pressey's subsequent work with similar devices, that Peterson was following Pressey's principles which in turn, were based ultimately on the theories of Edward Thorndike (Pressey, 1926; 1927; 1950).

Although the chemical version of the self-instructor and tester was patented (Peterson, 1931) neither the chemical nor the mechanical version appears to have been used widely at that time. Both designs were resurrected by Pressey and others subsequently.

Pressey's punchboard

When Pressey approached the United States Navy with information about his testing/teaching machines, he also informed them of mechanical and the chemical self-instructor trainer testers, but no interest was shown until after the end of the Second World War (Pressey, 1967). Pressey later received funding from the Special Devices Center of the Office of Naval Research (ONR) to develop both the mechanical and chemical versions of the self-instructor trainer tester (Pressey, 1950).

Improving the Peterson's envelope-type self-instructor trainer tester, Pressey (1950) designed a more solid version, consisting of a faceplate and baseplate made of pressboard, and an answer key made from plyboard. In Pressey's prototype, a narrow strip of paper is placed between the faceplate and the answer key, and the entire assembly is held together with screws. Pressey (1950) calls the device a *punchboard*. It is also referred to as a *pocket tutor* (Briggs, 1947). The punchboard, measuring approximately 3 inches by 5 inches (76 mm by 127 mm) is similar to the pierced, interlocking metal plates used in conjunction with Pressey's tabulating and scoring machine. Pressey's punchboard contains 15 rows of holes, with each row divided into two adjacent columns. The rows in each column each contain four holes. The holes represent the number of responses possible for each question. Each row and column of holes may be identified either by letter or by number. Figure 60 (after Pressey, 1950) shows an exploded view of a punchboard similar to Pressey's prototype of 1950. Numbers or letters used to identify specific rows and columns of holes are omitted as are the screws used to hold the assembly together.

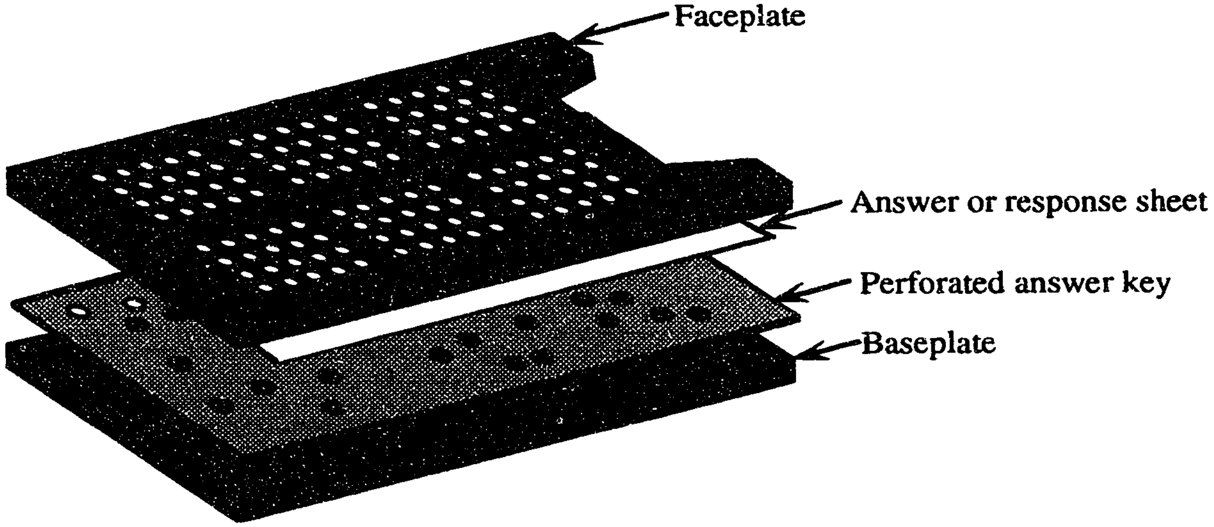


Figure 60. Exploded view of a Pressey-type punchboard

The type of cheating possible with the Petersons' envelope device is not possible with Pressey's punchboard. The punchboard may be used with a minimum of supervision, therefore. This is a desirable feature, particularly in the military, where it seems that there is an insufficient number of instructors at crucial times. As well as examples noted from ancient Rome (see Chapter II) Davis (1948) reports that by 1943, there was an acute need to train a rising number of new air-crews quickly without a correspondent increase in the number of instructors. In a similar vein, Briggs (1947) states, "Had such methods [of mass training] and special devices been used on a large scale immediately after Pearl Harbor, the training of needed personnel might have been much more economical and expeditious" (p. 215).

The United States Navy did use a version of the punchboard during the 1950s, referred to as device 20-E-2-e (Fry, Bryan & Rigney, 1960; Foltz, 1961). This version of the punchboard could accommodate up to 80 responses. Fry, Bryan and Rigney (1960) report that the Navy had distributed 1,200 punchboards for use by 1958, but that the manufacturer of them could not meet the Navy's requirement of 15,000. Problems with supply, changes in Naval administration and training policy, were all likely factors that contributed to the Navy's subsequent decision to discontinue using punchboards (Pressey, 1967).

Relationship to theories of learning

Pressey (1950) notes that the major features of the device are immediate feedback to the user and ease of scoring. Pressey (1967) considers feedback to be the most important feature, since he claims that it assists the user in two ways,

> initial right answers about which the learner was somewhat uncertain were confirmed as right and so likely to be made again, and (by far the most important effect) initial wrong answers were at once identified as such in immediate juxtaposition to the right answer, and wrongs were thereafter avoided. (p. 331)

Pressey (1950) also maintains that immediate feedback on whether a selection is correct or incorrect enhances the speed of instruction. He contends, therefore, that instructional devices of this kind are especially suited to occasions where the rapid training of a large number of individuals is required. Pressey (1950) states, "such devices [punchboards] spot each learner's weaknesses and assure their correction more adequately and immediately than could any human instructor" (p. 418). This aspect of the theory implicit in Pressey's punchboard seems to be congruent with Edwin Guthrie's principle of association. Guthrie (1942) states, "A stimulus pattern that is acting at the time of response will, if it recurs, tend to produce that response" (p. 23). It may be argued, therefore, that by modifying a students' incorrect response immediately, the likelihood of the student making the same error the next time that particular question is encountered is diminished. While this theory, or one similar to it, appears to underlie Pressey's insistence that immediate feedback enhances learning, some researchers contend that immediate feedback is not necessary.

Briggs (1964) a former doctoral student of Pressey, maintains that to understand the process of learning, especially when considering operations described as *verbal learning*, a distinction must be made between *learning* and *retention*. Citing findings from contemporary research, Briggs (1964) contends that while *learning* may be affected by the extent to which the question and the instructive feedback are contiguous, *retention* is enhanced by a delay in feedback. Moreover, Briggs (1964) states, "It is only one step more to hypothesize that the more difficult or complex the verbal task, the more benefit may be expected from the increasing delay [of instructional feedback]".

While one may conclude that the view of Briggs (1964) is new, the findings of Ebbinghaus (1885/1913) presented almost eighty years earlier, lead to a similar position. Ebbinghaus (1885/1913) notes a prevalent assumption that was common during his time, "'ideas become associated if they are experienced simultaneously or in immediate succession'" (p. 108). While such a doctrine of association may be significant in the initial acquisition of an idea or an association between a stimulus and a particular response, Ebbinghaus (1885/1913) found that such association or contiguity has little to do with retention or with the cognitive associations of ideas. Furthermore, he contends that a delay between response and instructional feedback, within defined limits, leads to increased retention. Ebbinghaus (1885/1913) states, "the directness or indirectness of the sequence is without effect upon the general nature of what happens between ideas which succeed each other" (p. 108). Controversy continues as to whether or not a delay in instructional feedback improves the overall condition of learning in an individual. To be sure, Pressey (1950) indicates that his position as well as that of Thorndike may be investigated further, implying that further research might lead to changes in the position. It is debatable, therefore, whether or not the method of pedagogy that Pressey's punchboard employs, immediate feedback, is as efficacious as other methods. Pressey did design other versions of teaching machines that also embody the principle of immediate feedback.

Angell's and Troyer's punchboard

Basing their work primarily on the earlier efforts of Pressey, the Petersons and the United States Armed Forces, Angell and Troyer (1948) developed a type of punchboard by 1945. Angell and Troyer (1948) fabricated their version from heavy cardboard of such dimensions that a standard 8.5 inch by 11 inch sheet of paper could be used as an answer sheet. Instead of using a perforated key to indicate a correct selection, Angell and Troyer (1948) designed their answer keys so that areas positioned below holes corresponding to correct responses are printed either with a colour, number, letter or other distinctive indication. The housing of the punchboard is designed so that the answer sheet rests a few millimetres above the answer key. In this manner, a hole of uniform size will be made when a stylus is punched through the paper. The holes enable the user to obtain feedback from the answer sheet as to whether the selection is correct or incorrect.

As well as eliminating the need for perforated answer keys which may be difficult and time-consuming to prepare, solid answer keys also prevent the sort of cheating possible with the Petersons' envelope version. Angell and Troyer (1948) also note that their punchboards are inexpensive to produce and that they may be transported easily because of their light weight and their lack of bulk.

Relationship to theories of learning

From the findings of several studies, Angell and Troyer (1948) conclude that, "learning is significantly enhanced", when students are informed of their scores immediately (p. 85). Angell and Troyer (1948), claim that this feature of their punchboard is congruent with the theories of learning postulated by Thorndike, Guthrie, Hull and Tolman. While immediate knowledge of test scores may appear to be congruent with portions of each of these theories, especially when considered out of context, Angell's and Troyer's claim is misleading, since some of the theories are radically different. Examples include the differences between Thorndike's theory of connectionism, described previously in Chapter V, and Tolman's theory of learning that defines learning as the formation or modification of *cognitive structures* (Tolman, 1958). Angell and Troyer (1948) do not elaborate further on how their punchboard can be congruent with such disparate theories of learning.

Angell and Troyer (1948) designed their punchboard with the intention of creating, "simple, inexpensive, rapidly prepared, fool proof devices… for general use" (p. 84). It is clear, therefore, that they envisaged commercial production of their punchboard.

sheets of paper. The left-hand half of each sheet contains questions and the distractors, while the right-hand half is blank. Each sheet is underlain by a second sheet that contains marks on the right-hand half to indicate correct or incorrect selections (Sturwold, 1961; Finn & Perrin, 1962). To use the sheets properly, a special masking device must be employed. The mask, fabricated of metal, is rectangular in shape. It contains a rectangular opening on the left-hand side, and a smaller rectangular opening on the right-hand side. In addition, four evenly-spaced holes are placed above the rectangular opening on the right-hand side (Finn &Perrin, 1962). Figure 61, depicts the general appearance of an Alpha masking device.

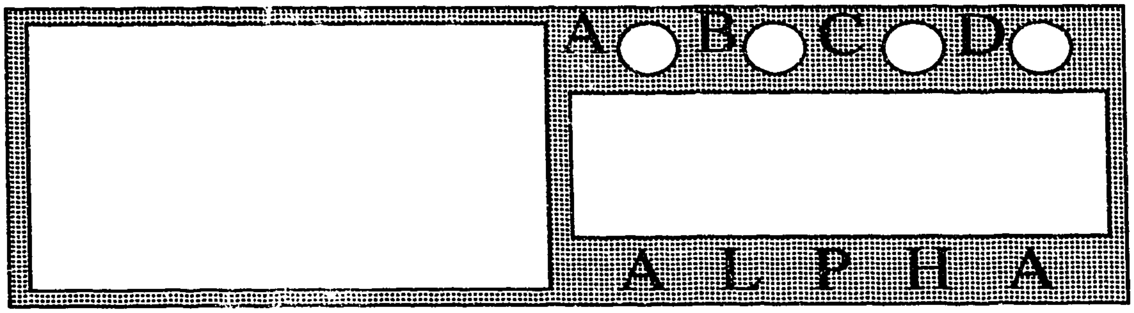


Figure 61. General appearance of an Alpha masking device

The masking device is intended to be placed on the question/answer sheet so that the left-hand rectangular opening frames a question. Using the blunt end of a pencil as a stylus, the user selects a response by punching the upper sheet through the corresponding hole. Once the hole is punched, the marks printed on the lower sheet will indicate whether the choice made was correct or incorrect (Finn & Perrin, 1962). The rectangular opening on the right-hand side is intended to frame written responses. This type of punchboard device allows a student to review the corrected responses. One disadvantage of the Alpha mask system is that it is susceptible to misuse, both intentional and unintentional. The lower sheet, which is reusable, may be damaged severely by a student using the pointed end of a pencil as the stylus. It is also important that the masking device be placed correctly on the question/response sheet, otherwise a punched answer may not be aligned with the correct question. It may be argued that the necessity of considering the stylus used as well as how the masking device should be placed, will add to the difficulty of the primary task, which is the answering of the questions. This factor will be considered in greater depth in a subsequent section. As with most punchboard-type teaching machines, the Alpha mask and sheets do not appear to have gained widespread use.

While it might seem that the relative low unit cost of punchboards as compared to other types of teaching machines would make them well-suited for schools, the initial capital cost for a class or a school set as well as the continuing cost of answer sheets probably discouraged many schools from making widespread use of punchboards. Teachers are also constrained in how they allocate the correct responses to test questions, since there are a limited number of prepared answer keys available for most commercial punchboards mentioned (Hendershot, 1967). While it is possible for a teacher to make their own answer keys, the time spent would probably be in excess of that spent on marking each exam by hand. Uncertainty of supply is another factor that probably limited the popularity of punchboard teaching machines. Although punchboards may continue to be used in some instances, they have not gained the widespread use that Pressey desired and anticipated.

Commercial Chemocards

Pressey (1950) reports that as well as developing a punchboard, he also conducted experiments using a modern version of the Petersons' chemical self-instructor tester, which Pressey refers to as a *Chemocard*. Measuring 3 inches by 5 inches (76 mm by 127 mm), this sheet contains 30 rows of four, one-eighth-inch (2.5 mm) squares printed with invisible inks. Fountain pens filled with a special solution cause the invisible inks to become visible when the pen is drawn across the squares (Pressey, 1967). The success of initial trials with the United States Navy prompted Pressey to have Chemocards manufactured commercially, by the Craftint Manufacturing Company of Cleveland, Ohio (Foltz, 1961). Pressey (1967) notes that these Chemocards were, "put in limited manufacture" (p. 332). It is not certain whether poor sales or a withdrawal of support from the Navy contributed to the short commercial life of this product. Pressey (1967) states, "personnel in the Navy office had changed again, and the cards were rejected offhand on the ground that the trainees would always be stealing the pens" (p. 332). Although Pressey's attempt at marketing the Chemocard was a failure, other enterprises marketed similar devices.

The New York Institute of Technology also experimented with chemical-type teaching machines (Foltz, 1961). Their version, unlike Pressey's, is printed on large sheets of paper that also contain questions (Finn & Perrin, 1962). The Consolidated Lithographing Corporation manufactured and marketed this version, under the trade name *Autoscore* (Foltz, 1961; Finn & Perrin, 1962). A special chemical solution is not required to reveal the invisible ink on the sheet. Instead, moisture applied by means of a small sponge or brush is all that is necessary to make the inks visible. A correct choice turns green, while an incorrect selection turns red (Foltz, 1961; Finn & Perrin, 1962). While the Autoscore may be less expensive to use than the Chemocard, since a special solution is not required, the Autoscore is susceptible to damage by inadvertent moistening. As well as spills, it is possible that the moisture of a sweaty palm can reveal several areas of the answer section. There is no indication that the Autoscore gained widespread use.

While chemical-type teaching machines may seem to be relatively inexpensive, they have not found favour with most educators. The principle of using invisible inks has not disappeared, however. A system of books that require the use of a chemical pen to reveal the answers continues to be marketed. Manufactured by Lee Publications, these books contain games, quizzes and puzzles, and they are marketed as a form of individual entertainment. Some learning is possible from some of the quizzes. One question, for example, asks for the pseudonym of Iosif Dzhugashvili. Four choices are given, Mussolini, Adolf Hitler, Joseph Stalin and Kirk Douglas (Lenkoff & Garrett, 1986). A small line is drawn in front of each name and the user rubs the area in front of the name selected with the special pen. An incorrect selection reveals the word *no*, while the correct selection reveals the word *yes*. In this manner, one may learn that the correct pseudonym is Joseph Stalin. Not withstanding the potential of the books to function in a manner similar to Chemocards, the publishers of these books market them as a form of entertainment rather than as instructional devices. It is probable that there is a greater, more stable market for entertainment devices than there is for instructional devices. Like some of the instructional devices mentioned by Locke (see Chapter IV) chemical-type teaching machines appear to be more successful as entertainment or as objects of amusement, rather than as instructional devices for formalized education.

Pressey's erasable overprint method

Pressey (1950) states that although he considers his earlier mechanical testing/teaching machines to be successful, he concedes that such machines, "could readily be made yet more compact and convenient" (p. 446). While Pressey (1950) mentions chemocards as an example of a simpler design, problems such as the theft or loss of special pens

(Pressey, 1967) likely induced Pressey to design simpler devices that do not require special equipment. In support of this position, Pressey (1963) states, "more convenient autoinstructional cards are possible. Instead of a pen with special ink, only a pencil may be needed... a stroke of its eraser, breaks through an overprint to reveal a 'c' underneath when the right answer is found" (p. 5).

Pressey developed a rudimentary version of this type of *autoinstructional card* by 1964. This early version consists of multiple-choice questions printed on a sheet of paper. Parentheses are printed in front of each distractor. A letter R is printed inside the parentheses next to the correct or *right* answer. To prevent the student from observing this indicator initially, Pressey and his assistants filled the spaces between all of the parentheses with smudges made with pencil (Pressey, 1964b). In use, an eraser is employed to remove the smudge next to the desired selection. The process continues until the letter R is revealed. In this manner, Pressey (1964b) contends that the user obtains, "immediate feedback as to the correctness of each one of their choices and guidance to the right answer" (p. 361).

As with most of his earlier inventions and developments, Pressey envisaged commercial potential for this overprinted card-type teaching machine (Pressey, 1964b). One firm, Van Valkenburgh, Nooger and Neville, had already been manufacturing instructional devices that entailed the erasure of an overprint. Instead of using pencil smudges, the overprint consists of an opaque ink that can be removed easily by erasing or by abrasion. These devices were not invented by Pressey, nor do they appear to have been derived from his work (Fry, Bryan & Rigney, 1960). In consequence, these antecedent overprint devices will be described in a subsequent section.

Combining Pressey's idea with the opaque overprint technology licensed to them, Van Valkenburgh, Nooger and Neville marketed a wide range of response cards and answer sheets by 1965, using the name *trainer-tester* (Van Valkenburgh, Nooger & Neville, 1965). The cards and sheets are intended to be used in the same manner as Pressey's crude experimental version. The layout of the answer choices are similar to the way they are laid out on the chemocards. A silver-coloured overprint ink is used to obscure the area next to each number and letter on the trainer-tester cards and sheets (Finn & Perrin, 1962). The marketing strategies used were low cost and simplicity of operation as compared with the mechanical teaching machines popular at that time. Th unit price per card or sheet remained below 15¢ (Van Valkenburgh, Nooger & Nevill 1965; Hendershot, 1967). Unlike earlier attempts to market punchboards and chemocards, the trainer-tester response cards appear to have remained in production several years. A lack of information precludes knowledge of total sales, prevalent markets, and whether such cards continue to be available.

Relationship to theories of learning

By the time the trainer-tester answer cards and sheets were developed, Pressey's enthusiasm for mechanical teaching machines had waned. The popularity of the mechanical teaching machines based on Skinnerian behaviorism surprised Pressey and prompted him to examine their appropriateness. In many instances, Pressey contends that complex teaching machines are unnecessary because they add to the difficulty of the task rather than simplifying it. Pressey (1964a) states that he, "received, as a bonus for a five-dollar purchase at a supermarket, a 'teaching machine' made of pasteboard... The program sealed into the bonus volume could have been put, in usual textual form, in a six-page folder" (pp. 361-362). Pressey was also critical of the principles of Skinnerian behaviorism embodied in such machines (Pressey & Kinzer, 1964). As well as reducing instruction to *page turning* and to minute *frames*, Pressey contends that the principles of Skinnerian behaviorism are misapplied to human learning. Pressey (1967) states,

> I remain of the conviction that a distinctive cognitive theory rather than an animal-derived stimulus-response theory is still to be found to explain meaningful human learning adequately, and that simple objective feedback devices could so greatly facilitate such learning as largely to remake our educational procedures. (pp. 333-334)

Pressey remained convinced that teaching machines of his design are more effective because they are based on theories of learning that have been applied in classrooms for many years (Pressey & Kinzer, 1964). Moreover, Pressey (1964b) predicted a demise in the popularity of teaching machines based on Skinnerian behaviorism. Several factors contributing to Pressey's prediction are discernible from his work: exaggerated claims about the effectiveness of the devices and improvements in student achievement, both by manufacturers of teaching machines and by educators who advocate the principles of Skinnerian behaviorism; crass exploitation of the market by overly ambitious manufacturers; misapplication of a learning theory first tested on lower animals and evaluated with human beings after teaching machines embodying the learning theory are in place; some learning theorists and educators looking for a neat and potential quick *fix* for a scholastic educational system perceived by some to be in peril (Pressey, 1963; 1964a; 1964b; 1967). Pressey (1963) indicates that the last factor mentioned is the most disturbing, "Most remarkable of all is it to see learning theorists, hypnotized by the plausibilities of a neat theory, trying to teach that human as if he were a pigeon" (p. 5). While the severity of Pressey's criticism of Skinnerian behaviorism may be debated, the factors that Pressey identifies as impinging upon teaching machines specifically, and instructional devices in general, are worthy of further study. Such analysis is undertaken in Chapter IX.

U. S. Industries' ready/review

Pressey's advocacy of teaching machines being of simple design where possible, appears to have been considered by several companies marketing teaching machines. One company in particular, U. S. Industries, introduced a device in 1963 that seems to be a simplified version of Pressey's mechanical testing/teaching machines. Consisting of a slotted metal and plastic case that houses specially prepared punched cards, the *Ready/Review* machine presents a sequence of multiple-choice questions (U. S. Industries introduces device, 1963). The cards are designed so that when a stylus is inserted into the correct slot and is moved towards the upper end of the housing, the next question becomes visible. The stylus and card will not be permitted to move if a slot representing an incorrect answer is selected. This condition indicates that the selection is incorrect and that another selection must be made (Hendershot, 1964).

Like punchboards, chemocards and overprinted trainer-testers, the ready/review machine was less expensive than mechanically-elaborate teaching machines. In 1963, the unit price of a ready/review machine in the United States was $2.98. An additional $1.98 is required for each program of cards (U. S. Industries introduces device, 1963). Initial sales of the device appear to have been good, since it is reported that in one particular book and stationery store in the City of New York, "400 devices and over 1,000 courses were sold" during the first month the machine went on sale (U. S. Industries introduces device, 1963, p. 5). It appears that the general public as well as the educational market were targeted for sales. The trend to high sales does not seem to have continued, since supply catalogues discontinue listing the ready/review machine by 1967 (Hendershot, 1967; 1969).

Not all teaching machines invented during the first half of the twentieth century are centred on the work of Pressey, or are derived from it. There are several known examples of teaching machines that were developed both from a perceived need and from the development and use of teaching aids.

Examples of other teaching machines invented before 1950

M. E. LaZerte

LaZerte's interest in and development of teaching aids is noted in Chapter V. While it is most unlikely that LaZerte knew Pressey or was even aware of his work, LaZerte also concluded that many tasks done by a teacher might be undertaken by a machine, thus providing the teacher with more time to deal with matters that require personal attention. While it is not clear whether Pressey designed his teaching machines from the basis of a particular theory of learning, or whether he applied an established theory of learning to the devices once they were constructed, it is clear that LaZerte considered the theoretical aspects of learning, as well as practical aspects, before he constructed his teaching machine. Most of LaZerte's practical pedagogical experience concerned teaching arithmetic and mathematics, so most of his work is centred in this subject area. This concentration does not mean, however, that the principles of learning he developed are valid only for those specific subject areas.

LaZerte concluded at an early date, from observations made while a teacher and later a school inspector, that too many educators emphasize the learning of the correct answer to a problem or question rather than emphasizing the learning of the principles and processes that lead to the correct answer. LaZerte (1926) states, "the ability of pupils to find correct answers to problems in arithmetic is a poor measure of their actual problem-solving ability" (p. 102). He also notes that, "much problem-solving is but a slavish adherence to type methods of procedure which become associated with certain language and number situations that exist in the presented problem" (LaZerte, 1926, p. 102). LaZerte interpreted these observations as indications that the pedagogical methods employed by many teachers are unsatisfactory, since the action of ascertaining a correct answer to a mathematical problem does not indicate to the teacher whether or not the underlying problem-solving strategy or concept has been either learned or understood by the student. These findings are, of course, not new. It should be recalled that Quintilian had made the same observations (see Chapter II). Both LaZerte and Quintilian also conclude that repetitive instruction such as drill and plain memorization do not provide the student with an adequate facility for problem-solving (LaZerte, 1933). It is important to note that Quintilian's and LaZerte's contention is at variance with Thorndike's theory of learning as it stood prior to 1930 (see Chapter V). LaZerte's contention, therefore, is opposed to the theories of learning that Pressey claims are embodied in his teaching machines. Apart from other evidence already mentioned, the differences between the theoretical bases of Pressey and LaZerte indicate that LaZerte's teaching machines were not derived from the work or the theories of Pressey.

Like Pressey, LaZerte came upon the idea that mechanical contrivances could provide instruction, through his attempts at assessing and measuring the problems students undergo to solve problems in arithmetic. Most of LaZerte's work in this area was undertaken while he was a doctoral student at the University of Chicago.

Judd's theory of learning

LaZerte's doctoral work was under the supervision of Charles H. Judd (1873-1946). Judd, who received his doctoral degree in psychology at Leipzig, Germany under the guidance of Wilhelm Wundt, did not agree with the predominantly American theories about behavior and learning known generally as *behaviorism* (Judd, 1932). Judd's criticism of behaviorism is based primarily upon two positions. First, Judd (1932) maintains that while most American-trained psychologists were open to ideas and influence from Europe during the late nineteenth century, this tolerance for foreign views diminished by the beginning of the twentieth century, with the result that later works by Wundt and other European psychologists were largely ignored. The only new ideas to arise in

American psychology, therefore, were derived mainly from existing American theories without the benefit of external input and criticism. Second, Judd (1932) contends that most behavioristic theory is nothing more than an extreme reaction to introspectionism. Explaining the popularity of behaviorism among American psychologists and educators, Judd (1932) states,

> The reason why some of the recent behaviorists flourish is that they have reduced psychology to a few simple formulas which can be carried in the mind without serious mental effort. They have simplified the mental universe as one might simplify the celestial world by mistaking the stars of the first and second magnitudes for the real cosmos. (p. 219)

Judd (1932) contends that an atomistic approach to psychology and to learning as well, does not result in a complete view of the learning process or of behavior. Methods of pedagogy derived from a behavioristic basis, therefore, are likely to be flawed or incomplete at best. Judd advocates the use of experimental processes unencumbered by *a priori* dogma, to investigate learning, behavior and the efficacy of methods of pedagogy. Judd (1932) states, "There is much productive laboratory work to be done on human behavior, especially the higher forms of behavior such as language. When this experimental work is done, there will be very little ground for the shallow dogmatism of the self-styled behaviorists" (p. 228). The tenets of connectionism as advocated by Thorndike and to a lesser degree by Pressey, are also at odds with Judd's theories. Accepting some of Wundt's postulates, Judd (1932) states, "Wundt never attempted to explain the higher mental processes by piling up great collections of lower mental processes... He believed that when mental processes become complex, there appear new forms of experience which no lower stages of mental life exhibit or remotely experience" (p. 219). Judd also accepted Wundt's *historical method* in psychology, where earlier findings and developments are applied to new research and theory (Judd, 1932).

Since Judd maintains that the education of human beings is often concerned with *higher mental processes*, pedagogical methods appropriate to these higher processes should be used, rather than approaches that address simple or *lower* mental processes. On the basis of several experimental studies concerned with attention, learning and memory, Judd (1918) advocates the use of *classroom devices*. A classroom device is intended both to hold the attention of the student as well as to facilitate the comprehension of a logical sequence or a concept, both being higher mental processes. What Judd means by classroom devices are teaching aids, although he notes that more elaborate and complex devices may be both invented and used in productive ways in the classroom (Judd, 1918). Employing aspects of Wundt's historical method, Judd (1918) bolsters his advocacy of classroom devices (teaching aids) by noting their successful and productive use by educators of the past such as Pestalozzi. The use of instructional devices as integral parts of the so-called *laboratory method* are also cited by Judd as examples of effective and appropriate methods of pedagogy. Judd (1918) also describes how the laboratory method has been adapted and used successfully to teach seemingly *un-scientific* subjects such as history and English composition (see Chapter IV for examples of such teaching aids).

It is clear from the previous paragraphs, that LaZerte's theories of learning are congruent with those of Judd. LaZerte shared Judd's contention that it is necessary for a student to develop a *concept* of what is being taught, rather than simply being able to parrot it. Judd (in LaZerte, 1933) states that, "while formal drill gives a superficial mastery of arithmetic processes, it fails utterly to give pupils that higher training in reasoning which might be derived from an effort to understand the meaning of number operations" (p. x). LaZerte endeavored initially to devise methods and apparatus to evaluate students' comprehension of problem-solving processes in a scientific manner.

Envelope test

Through the use of one method and apparatus in particular, LaZerte discovered that as well as revealing a student's mastery of a logical sequence, the apparatus could also provide instructive feedback to the student and that it also facilitates individualized pacing through the sequence. LaZerte (1933) refers to the apparatus as the ***envelope test***. A number of envelopes and printed cards comprise the apparatus. In use, the subject is presented with a large envelope on which is typed a question. The subject is told that further information and instructions will be found inside the envelope. Two smaller envelopes, located inside, each have a different problem-solving procedure typed on the outside. The subject must select only one of the envelopes, the one that is thought to display the correct procedure. This envelope in turn contains two more envelopes with further steps. After further selection, the student is left with one envelope, inside of which is a card. The card contains the last step of the problem on one side and a message on the other. Only one of the cards in the envelope array states, "This is the correct card"; the others state, "You are wrong. Go back to the beginning and try again" (LaZerte, 1933, pp. 12-13). Figure 62 illustrates the hierarchical nature of the envelope test.

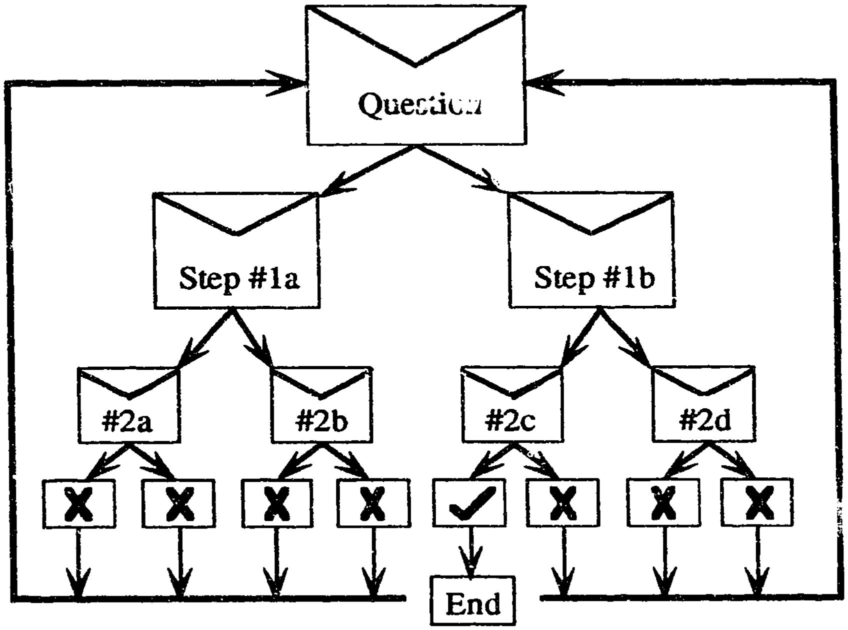


Figure 62. Schematic operation of LaZerte's envelope test

LaZerte notes that both the number of cards and envelopes is altered to accommodate questions of different complexity. He also states that some sequences possess intermediate blank cards or envelopes that indicate to the subject that he/she is on the wrong track. LaZerte intended this modification to save time, informing the subject of an erroneous choice early in the procedure. Although a blank card or envelope informed the examinee that an error had been made, it did not provide any corrective hint or cue (LaZerte, 1933). In this manner the envelope test did not instruct the examinee, and the procedure measured only what the examinee knew at the time of the test. The envelope test possess the capability, nevertheless, of providing instruction in problem-solving strategy, if it is desired. Instead of providing printed cards with remedial materials, LaZerte designed a more elaborate device that could provide instructive feedback without the necessity of supervision. With the envelope test, LaZerte had created a rudimentary branching program anticipating those found in many *scrambled books* and in some teaching machines produced 25 years later (see Lumsdaine & Glaser, 1960).

There are distinct disadvantages to the envelope test. In order to prevent cheating, a supervisor has to be present while the test is in progress. The supervisor, or other qualified person, has to restore the cards and the envelopes after each test. Each use of the envelope test, therefore, requires the undivided attention of a supervisor who, if a different system were used, could be supervising several individuals simultaneously. Considering the limitations imposed by the materials used and the time required to prepare them, the envelope test is able to present only a relatively small number of decisions to the subject. This fact means that one could possibly guess the correct sequence of envelopes as well as the correct card (LaZerte, 1933).

LaZerte's problem cylinder

To alleviate the problems and limitations of the envelope test, LaZerte devised, and had constructed by 1929, a teaching machine he named the *problem cylinder* (LaZerte, 19[illegible]). The problem cylinder consists of a frame of wood and brass which houses five laminated wooden cylinders. Figure 63 depicts the front view as well as cross-sectional views of each e[illegible] apparatus.

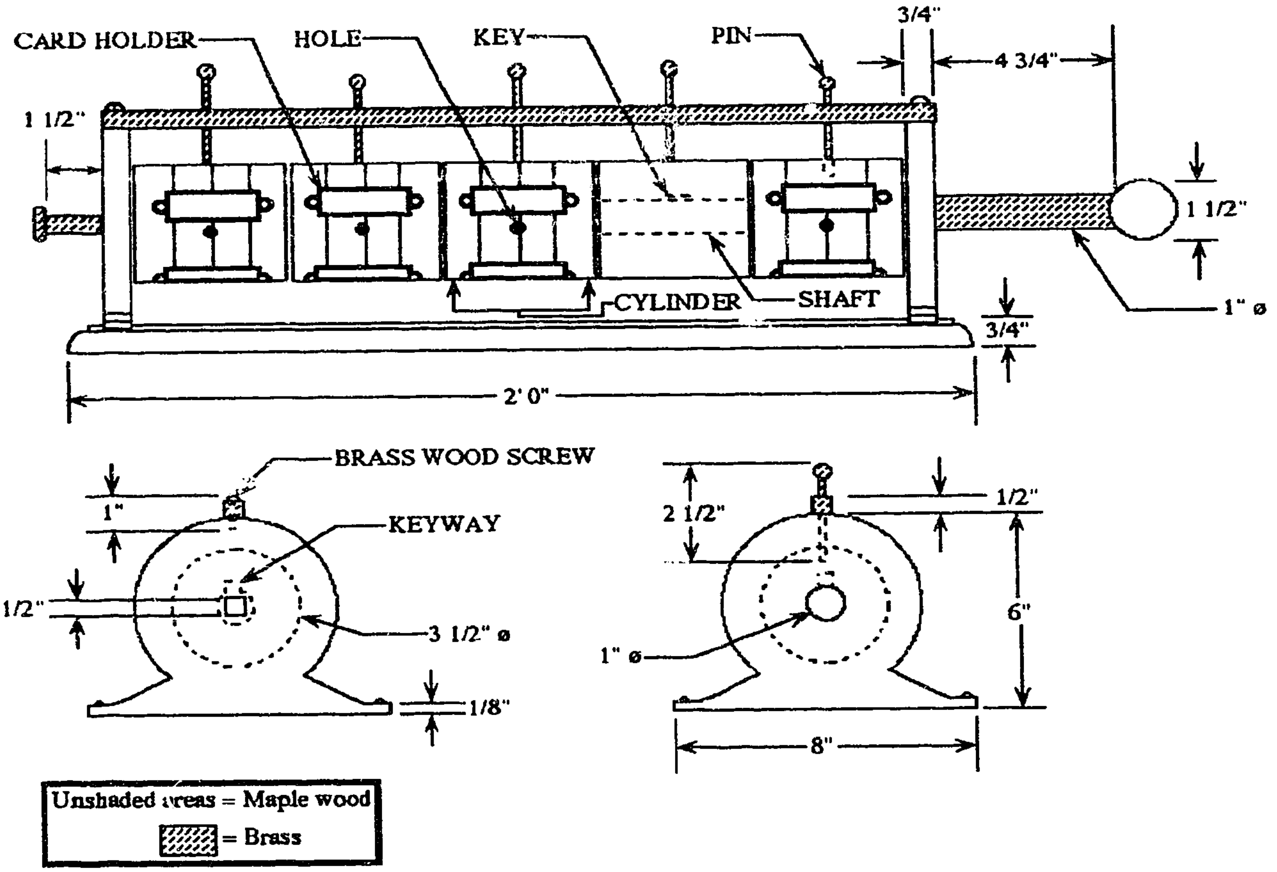


Figure 63. General appearance of LaZerte's problem cylinder

The cylinders are constructed so that a keyway is present throughout their length. The centre laminations are also designed so that the cylinder can be rotated around a key, if it is positioned in the centre of the cylinder. Each cylinder possesses five brass card holders, evenly spaced about the circumference. The card holders hold segments of equations or portions of a problem-solving strategy. In between each card holder is a small hole into which one can insert a brass pin located in a bar running along the top of the frame. The pin holds the particular cylinder in the selected position. The cylinders are mounted horizontally onto a tubular brass shaft which also has five steel keys fastened to it in a linear fashion. The keys are arranged so that they are normally located within the centre of each cylinder, thus permitting each cylinder to rotate freely and independently. A square brass rod, which passes through a squared hole in the frame, is attached to one end of the shaft. The squared rod prevents the shaft from rotating, so that the keys on the shaft will always be positioned along the top of the shaft. If all the cylinders are rotated on the shaft so that their keyways are aligned with the keys, the shaft can be slid one and one-half inches (38 mm) to the right. This action indicates to the user that the problem presented has been solved correctly (LaZerte, 1933). The operation of the problem cylinder is similar to some cylinder [illegible] locks that are used at the present time. When the correct numbers are selected on the cylinders of the lock, the keyways of the cylinders are aligned allowing the release of [illegible] shaft within the lock.

A total of 3,125 arrangements of the cylinders is possible, so it is most unlikely that an individual would guess the correct position of all five cylinders. In operation the subject is presented with a mathematical problem and is then instructed to solve it, starting with the left-most cylinder and proceeding to the right. Every cylinder holds five cards, each of which displays a part of a problem solving strategy. The subject selects what is believed to be the correct strategy among the five cards on each cylinder. This is accomplished by the subject rotating each cylinder so that the desired information faces him/her. After each selection is made, the subject inserts a brass pin into a hole in the top of the cylinder, to prevent it from being moved while the next selection is undertaken. When it is believed that all five cylinders are in the correct position, the subject pulls on the shaft or knob. If the shaft does not slide to the right, one or more cylinders are positioned improperly, and this is an indication to the subject that a mistake in the steps of solving the problem has been made and that one should try again. By reviewing the information on the cards, it is possible for the subject to ascertain at which step of the process an error was made. This process is accomplished at the pace selected by the student, since there is no teacher intervention unless the subject requests it.

LaZerte (1933) found that the problem cylinder was very intriguing to students and was highly motivational. He states that, "all subjects were very much interested in the problem presented to them. After the experiment was completed many requested to continue their efforts. Motivation was strong throughout" (p. 60). In a fashion similar to that of the envelope test, the problem cylinder could be arranged so that fewer than five cylinders could be used. In such cases, those cylinders not in use would not have cards inserted in their card holders. These cylinders would also be pinned in the unlocked position.

Unlike the envelope test, the problem cylinder could be used without constant supervision, since there was no easy way in which the subject could cheat or sabotage the machine. Besides being a testing device, the problem cylinder could be used to demonstrate logic or the logical analysis of a problem. It might be asked, given the reported success of the apparatus and its apparent acceptance by the students, why was there no attempt made to have the problem cylinder mass-produced and used in the schools in order to improve pedagogy and student learning. The answer is provided by LaZerte's findings. Although high motivation and interest were attributed to the problem cylinder in a kind of *novelty* effect, LaZerte (1933) also discovered that the skill required to understand and to manipulate the apparatus added to the difficulty of the problem being solved, "it is apparent that the task of solving the problems on the cylinder is much more difficult than when presented in the usual form" (p. 65). Data gathered from comparison groups verified his findings (LaZerte, 1933). It seems probable, therefore, that if LaZerte's problem cylinder were to be used successfully as a teaching machine, instructions and practice exercises would have to be provided, so that the manipulation of the machine would not add to the difficulty of the problem presented. That is, much time and effort would have to be expended on training in the use of the machine. Given this drawback, LaZerte concluded that the use of a teacher was more efficient and more effective than the use of his problem cylinder. Although the underlying pedagogical principles of permitting a complex operation to be subdivided into smaller, discrete steps and employing a machine to provide instruction, were found by LaZerte to be valid, the factor of the machine adding to the complexity of the problem was accorded greater importance, with the result that further development of the apparatus was dropped. Had his experimental studies shown the problem cylinder to be a successful teaching device, or if LaZerte, like B. F. Skinner 25 years later, had decided to market the device, in spite of indications that it would not be successful in the education market, the problem cylinder could probably have been manufactured inexpensively. LaZerte was not the only individual independent of the influence of Pressey to design teaching machines during this period.

Beeler's teaching machine

By 1933, Samuel Beeler, an industrial arts and special education teacher with the Benton Harbor school district in Michigan, had also produced a teaching machine. Recognition of tools and their correct names is one area of concern in the subjects taught by Beeler. While the process of teaching the names of common tools and their identification may not be a time consuming task with most students, Beeler (1933) found that much additional time was required, "with boys in special groups who are somewhat slower than average" (p. 50). Instead of spending additional instructional time on such tasks, Beeler designed an apparatus that could be used by the students themselves to learn the names of particular tools. Like Pressey and LaZerte, Beeler appears to have designed his teaching machine on the basis of a perceived need. It does not seem that Beeler constructed his device according to the tenets of some explicit learning theory. The device does embody a theory of learning implicitly, however. It is noted in previous chapters that many earlier teaching machines and teaching aids reflect the theory that there is a natural sequence of learning in human beings, progressing from concrete to abstract. The modern version of this theory as codified by Bruner (1961; 1964) has also been noted. The theory that learning proceeds from concrete to abstract appears to be implicit in the teaching machine designed by Beeler. Figure 64 (after drawing in Beeler, 1933, p. 50) depicts the general appearance of Beeler's teaching machine. It should be noted that the dashed lines represent hidden components and wires.

Beeler (1933) envisaged his teaching machine being used to teach tool recognition and the association of a name with an image of a particular tool only. The device uses illustrations (iconic representations) of the tools as well as names (abstract symbols). Both the illustrations and the names are printed on cards that may be removed from the board. Although Beeler does not mention it, his teaching machine may also be used to instruct the relationships of different abstract symbols that might be encountered in some industrial education courses. It is for this reason that Figure 64 contains illustrations of tools as well as particular abstract symbols common to the fields of electricity and electronics. Given the intended use of the machine, it is unlikely that illustrations of tools and electrical symbols would be mixed, since they are usually parts of two separate areas of industrial education.

Two distinct types of stimuli are presented by this machine, if it is used in the manner Beeler (1933) intended, iconic representations of concrete objects and abstract symbols. The uppermost eight rectangles hold illustrations of tools or other concrete objects. The lowermost eight rectangles hold cards printed with the names of the objects depicted in

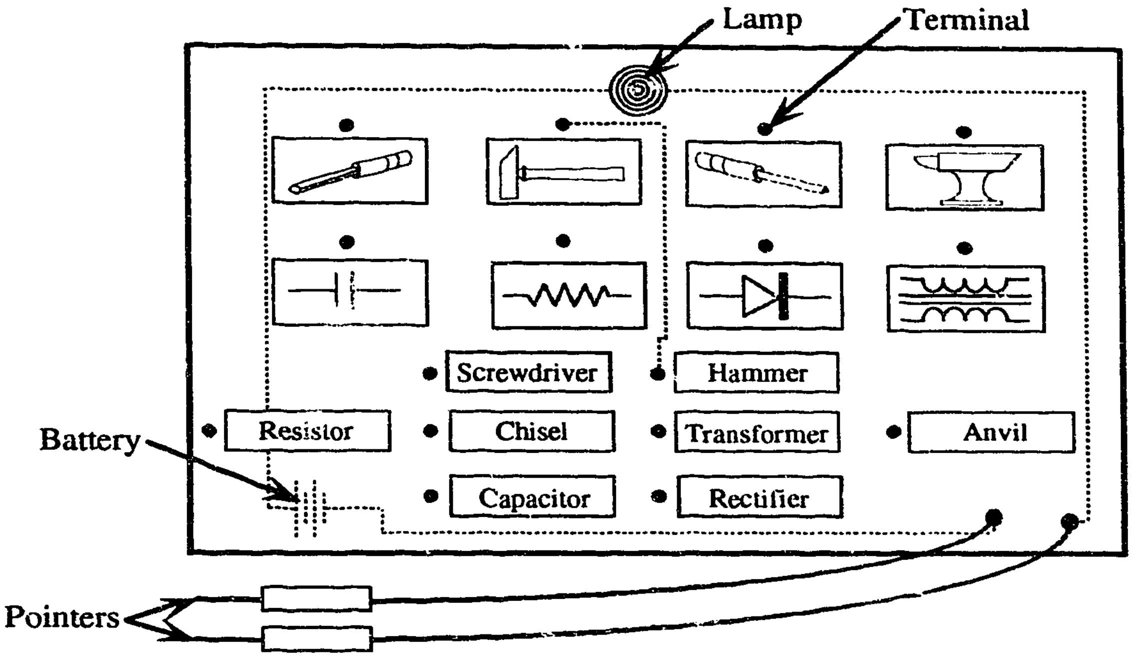


Figure 64. General appearance of Beeler's teaching machine

the illustrations. In order to use the machine, it is assumed that the students have sufficient mental facility both to recognize illustrations as iconic representations of concrete objects and that they can also read and comprehend the abstract symbols in the form of words (Beeler, 1933). If these criteria are met, then it is possible for the student to learn the association of a given word with a particular illustration of an object. There are two possible methods by which a student may use the machine.

An individual student may use the teaching machine by him/herself, or in cases where a student is likely to be confused by the apparatus, two students may work together. The problem of a teaching machine adding incidental complexity to the intended task, as noted by LaZerte (1933), appears to have also been considered by Beeler (1933) since he notes that the apparatus may be operated by two students, one to perform the operations and another to assist.

The designated *foreman* or assistant begins by placing the end of one pointer against a terminal next to the name of a tool, *hammer* for example. The student who is the *learner* in this instance takes the other pointer and places it against the terminal next to the illustration that is believed to represent the name, the second illustration from the left in the uppermost row in this case. If the selection is correct, as it is in this example, an electrical circuit is completed and the lamp will be illuminated if there are no malfunctions. No illumination usually indicates that an incorrect drawing was selected. With some students who are "slower than average" the use of an assistant is likely to diminish the potential for confusion and frustration. Instead of having to remember two discrete elements, which name was selected and the illustrations tried in combination, the *learner* by working with an assistant, may concentrate on the illustrations and their associations without having to remember which name was selected. The use of an assistant may also help to alert the teacher to any malfunctions that may occur with the teaching machine, such as a discharged battery, a burned-out bulb, or a broken wire.

While Beeler's teaching machine may also be used with so-called *normal* students, it does not appear that much time would be saved by using this method rather than demonstrations or lessons, since a considerable time is required both to arrange the names and drawings as well as to connect the wires correctly in the back of the machine. If the teaching machine is to be used for different objects, even more time is required, since the existing information must be removed before the machine can be prepared again. Another problem in using Beeler's teaching machine with *normal* students is that the machine is likely either to be boring, or to be seen as an annoyance that should be sabotaged. It is possible to sabotage the apparatus by placing the ends of the pointers together. This action will complete the circuit to the lamp and will drain the battery if left for a protracted period. The name cards and pictures may also be tampered with, so that the wired connections do not work the way they are intended to. It is clear, however, that Beeler (1933) intended his teaching machine to be used primarily with students considered to be deficient mentally.

While Beeler did not market his teaching machine commercially, knowledge of this type of teaching machine was spread by others who also promoted their use. For example, Dent (1942) describes an apparatus referred to as the *Electric Map*. The device is almost identical to that described by Beeler, but Dent (1942) does not indicate that it is suitable for use with mentally disabled students. While the availability of a commercial version is not noted, Dent (1942) provides a listing of materials and instructions whereby individual teachers can fabricate their own electric maps. It is not known how many teachers fabricated and made use of devices such as the electric map and Beeler's teaching machine.

Beeler's device represents one of the earliest examples of a teaching machine designed specifically for the needs of students with observable mental deficiencies. While it is arguable whether other teaching machines may also be used with such students, it is clear that Beeler designed his machine primarily from the basis of a perceived pedagogical need of a particular type of student. The idea of designing teaching machines for a specific type of student is not new, however. It should be recalled that the quintain was designed to instruct proper swordsmanship to military recruits. While the quintain was not adaptable to education generally, some other teaching machines designed for military applications have been adapted for general educational use.

Teaching Machines designed for military applications

The important rôle that instructional devices can play in the military has been mentioned previously in Chapter II. While the quintain eventually proved itself to be an effective and a useful teaching machine, military organizations tend to be skeptical of new instructional devices. A recent example of this skepticism is the initial rejection by the United States Navy and the American Air Force, of the Link Air Trainer simulator as being nothing more than an object for amusement (Kelly & Parke, 1970). Both of these branches of the American military came to realize the potential benefits of this type of instructional device before the beginning of the Second World War. There is evidence to indicate that most of the American military neither developed teaching machines or considered where or why they might be used until there was a demonstrable need for them. One such demonstrable need was that country's entry into the Second World War (Briggs, 1947; Taylor, 1947; Davis, 1948).

The general acceptance of teaching aids among educators in schools appears to have had an influence upon some aspects of military pedagogy. By 1943, for example, a training division of the United States Army was using several types of teaching aids (Witty & Goldberg, 1944). Teaching aids were considered not as substitutes for actual teachers, but as potentially useful adjuncts. Witty and Goldberg (1944) state that the use of teaching aids, "does not insure good classroom teaching, it does encourage rapid and thorough assimilation of subject-matter. It follows therefore that superior instructors generally secure access to varied and appropriate visual aids and use them judiciously" (p. 82). Teaching aids could be used effectively, provided there were sufficient instructors. A problem arose when the number of personnel to be trained exceeded the capacity of the instructors available. In such cases, either inferior training would be provided through traditional methods, or another method of instruction would be adopted. As we have seen with the quintain, teaching machines may be used successfully in such situations.

Once the branches of the American military were convinced of the necessity of teaching machines, it appears that military engineers, not educators and psychologists, were directed to produce such devices (Taylor, 1947). This approach revealed some serious problems. By not being aware of theories and methods of pedagogy, some military engineers designed apparatus that was unsound pedagogically. This problem was compounded further by deploying such apparatus before extensive testing could be carried out to ascertain both the effectiveness of the devices and whether or not they were appropriate for their intended purpose. Taylor (1947) states,

> It is at least possible that many of these instruments were worthless as trainers and, conceivably, some may actually have taught incorrect habits so that the subsequent learning of the proper habits was more difficult than it would have been if the trainer had not been used. (p. 90)

Taylor (1947) notes that this potential condition was recognized eventually, with the result that the Psychology Section of the United States military was employed to evaluate existing apparatus and to develop newer, more appropriate devices.

It is of importance to note that several individuals who served in the Psychology Section during the Second World War gained prominence later as proponents of teaching machines based on the tenets of Skinnerian behaviorism. Such individuals include: Leslie Briggs, Robert Gagné, Robert Glaser and Lawrence Stolurow (Davis, 1948). While their service to their country is not criticized, it is important to consider that their later advocacy of using teaching machines in schools might be based in part on their prior experience in the military, rather than through empirical analysis of needs within schools. The later rôle of the American military both in the development of teaching machines after the Second World War (Mead, 1949) and their encouragement in the use of teaching machines in schools through support of the National Defense Education Act and through public statements by high-ranking officials such as Admiral Hyman Rickover, suggest that perceived needs by the military were a major impetus of post-war teaching machine development and deployment. It is cogent, therefore, to consider some of the teaching machines developed by the military in the Second World War and also to examine how some of them were adapted to general educational use following the cessation of hostilities.

Automatic rater

While the United States Navy did not pursue development of Pressey's testing/teaching machines during the Second World War, the Navy and the other branches of the American military developed or used other teaching machines, some of which operate in a similar fashion to some of Pressey's machines. One example is the device known variously as the *automatic rater* (Pressey, 1950; Angell & Troyer, 1948; Fry, Bryan & Rigney, 1960) or as the *film rater* (Keislar, 1959). Angell and Troyer (1948) describe the external appearance of the device as a heavy (175 lbs., or 79.4 kg) cabinet-like housing, measuring approximately 26 inches (660 mm) across, 18 inches (457 mm) in deep, 48 inches (1 219 mm) high (p. 84). The housing contains an electro-magnetic mechanism that moves a filmstrip sequence past an enclosed projector that projects the image onto a viewing aperture located on the top of the housing. The filmstrips contain information and multiple-choice questions. When a particular question is displayed, the user selects a response by pressing one of five selector buttons adjacent to the viewing aperture. If the selection is correct, then the machine illuminates a green light, also on the machine. By pressing another button, the next image is projected (Keislar, 1959). If the selector button pressed represents an incorrect response, then the machine illuminates a red lamp, and the user must press a reset button. This action permits the user to answer the question again. The user is not permitted to proceed to the next image until the current question is answered correctly. The automatic rater also contains a recording device that draws a cumulative record graph of the user's responses. Correct responses are shown as a vertical movement of the pen, while incorrect responses are shown as a horizontal movement to the right (Keislar, 1959).

The configuration of the automatic rater suggests that the design includes little consideration of ergonomics. It is necessary for a user either to stand while using the machine, or to sit on a stool. This latter position is liable to be uncomfortable, since the housing has no provision for the knees. While comfort and ergonomics are perhaps not considered essential for military personnel, such factors are important to school-age users, since discomfort tends to result in diminished levels of attention and concentration.

Only one example of the automatic rater appears to have been produced, since it is always referred to in the singular, and since Fry, Bryan and Rigney (1960) state that *it* was later used in civilian experiments. While Keislar (1959) states that the automatic rater was used to teach aircraft identification while in use with the Navy, it seems likely that its use during the war was largely experimental, because it is unlikely that a single teaching machine would be sufficient to accommodate the numbers of personnel required to learn aircraft identification.

Relationship to theories of learning

While the theory of learning inherent in the automatic rater is not stipulated, it is likely that it embodied the principles of connectionism as found in Pressey's testing/teaching machines. The automatic rater was adapted for scholastic education after the Second World War, since Keislar (1959) reports using the device at the University of California at Los Angeles, in experiments teaching mathematical concepts to fourteen elementary school pupils. No mention is made of any specific modifications to the hardware.

Like LaZerte (1933), Keislar (1959) assumes that a logical understanding of a concept proceeds from simple elements to more complex elements, for example acquiring an understanding of the area of rectangles by constructing on the simpler concept of the area of squares. Keislar (1959) modified the questions presented by the automatic rater so that they reflected this progression as well as Judd's theory of transfer through verbal principles. As explained by Keislar (1959) this theory postulates that formulating a more complex *understanding* of a concept is dependent upon the individual acquiring a variety of verbal responses that may not be required immediately, but which may, through *intraverbal association,* be used later to develop the concept further. Appropriate intraverbal associations are defined as, "verbal principles, definitions, or characteristics" (Keislar, 1959, p. 250). Keislar (1959) contends that if this theory can be realized in practice with teaching machines, "the use of multiple-choice items in automated teaching results in something more than 'mere recognition' of the right answer" (p. 250).

In his experiment, Keislar (1959) endeavored to ascertain whether any differences are discernible between students who are taught the concept of the area of rectangles by the automatic rater and students who are taught by traditional classroom methods. Keislar's (1959) findings indicate that the experimental group performed "significantly better" than the control group (p. 253). While these findings suggest that the automatic rater is efficacious as a teaching machine for concepts, which would concur with the findings of LaZerte (1933) it should be noted that Keislar (1959) states that the control group were, "given no special instruction of any kind" (p. 250). This statement is not elaborated upon, so it is not clear if the control group actually received the same instructional content as the experimental group. The validity of the conclusions may be questioned, therefore.

In spite of his conclusion that the automatic rater can develop the understanding of concepts, which implies that teaching machines are versatile and more saleable, there is no evidence to indicate that the automatic rater was developed commercially. Although development of this type of electro-mechanical teaching machine was not pursued by civilian concerns, various branches of the United States military, devised more complex teaching machines based on the automatic rater as well as on the principles of Pressey.

Self-rater

Foltz (1961) claims that Briggs (one of Pressey's graduate students) designed an improved electro-mechanical version of Pressey's testing/teaching machines for the United States Navy. The device, called the *self-rater*, is likely similar in appearance and operation to the automatic rater. Foltz (1961) states that the prototype of the self-rater was manufactured by General Dynamics Corporation, who was also considering marketing a commercial version of the device. It is possible, however, that the self-rater is either another name for the automatic rater, or is a modified version of it. Descriptions of the self-rater are vague. Skinner (1958) describes the unit as a larger version of Pressey's testing/teaching machines that accepts items printed on "code-punched plastic cards" (p. 977). Foltz (1961) describes the self-rater as using "paper programs... and feedback by colored lights" (p. 90). It is likely that the automatic rater and the self-rater are similar since Foltz (1961) states that they, "differ in amounts of data storage, type of display, and the method of feedback. Display is by film, slide or cards, and feedback is provided by bells, buzzers or colored lights" (p. 35). A lack of more detailed information precludes a comprehensive description and analysis of the self-rater. There is sufficient evidence, however, to show that Briggs and others designed several complex teaching machines for the United States Air Force.

Subject-matter trainer

Briggs (1958) reports that by 1954, he and others working in the United States Air Force had developed an electrical teaching machine based on the principles of Pressey. Intended initially for military purposes, Briggs (1958) also states that the device may be used for civilian educational purposes. Mounted in a tall cabinet with a lid, similar in appearance to the automatic rater (see previous section) the subject matter trainer is more complex both in its operation and in the number of choices available to the user. The top of the subject matter trainer contains a viewing window on the left-hand side that permits the user to observe portions of a cardboard disk. Up to 20 questions, instructions and information are arranged along the circumference of the disk, so that when installed in the unit, a single question or portion of information is visible to the user at any given time. A system of micro-switches and relays operate in conjunction with notches in the cardboard disk to control the operation of the machine. Supplemental information such as wiring diagrams may be displayed on the inside of the lid (Briggs, 1958). To the right of the window is a replaceable rectangular panel containing smaller rectangles arranged in rows and columns. A push-button switch and a green-coloured lamp are located within each of these smaller rectangles. Written selections or illustrations may also be placed within the rectangles. These materials represents the responses available to the user (Briggs, 1958). A separate push-button switch is also located on the top of the unit. In particular modes of operation, this push-button switch, when pressed, will advance the cardboard disk so that the next question or *frame* of information is visible. Figure 65 (after photographs in Briggs, 1958; Lumsdaine, 1959) depicts the top of the subject matter trainer as it would appear typically to a user.

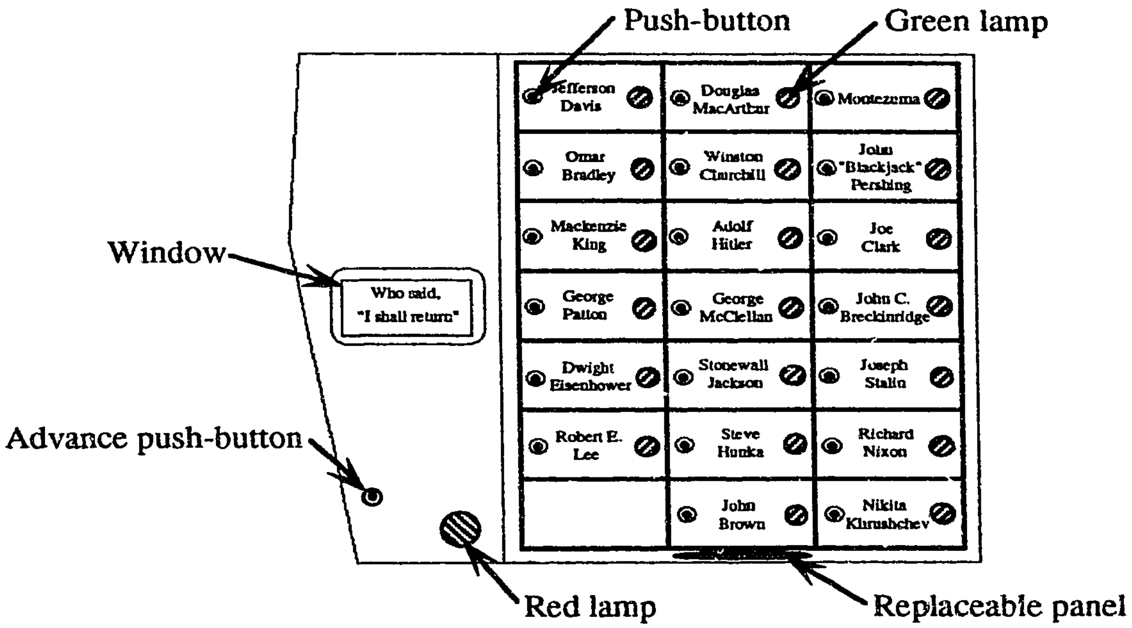


Figure 65. Typical appearance of the top of a subject matter trainer

While the general layout and principle of operation of the subject matter trainer is similar to that of Beeler's teaching machine, the subject matter trainer is capable of operating in any one of six discrete modes: coaching, single-error-permitted, practice, single-try, paced-practice and test modes (Briggs, 1958). The master switch as well as the selector switch for the different modes, are located within a recess on the left-hand side of the cabinet.

In *coaching* mode, the user must advance each frame of the program by pressing the special advance push-button. When a question is aligned in the viewing window, the machine will illuminate the green lamp located next to the information in one of the smaller windows that represents the correct response. The next question may be brought into view. This process continues through the entire sequence on that particular disk (Briggs, 1958). It is likely that this mode of operation is intended to acquaint the user with the way in which the machine interacts with the user, although Briggs does not state so directly. It seems that the designers of the subject matter trainer, like LaZerte with his problem cylinder, discerned that the operation of the device requires some skill and facility and that this factor likely adds to the difficulty of the subject matter presented by the machine. By acquainting the user with the operation of the machine before the intended task is attempted, the problem of handling two operations at once, working with the machine in the proper fashion and answering the questions presented, is diminished.

In *single-error-permitted* mode, the user receives no initial coaching. When a question is presented, the user selects the response by pressing one of the push-buttons. If the selection is correct, then the green lamp next to the selection is illuminated. This lamp indicates both a correct response and also signals the user that the advance push-button may be pressed for the next question to be displayed. If an incorrect selection is made, either a buzzer will sound or, if the unit is set-up differently, a red lamp located near the viewing window will be illuminated. As soon as the error is made, the machine illuminates the green lamp next to the correct selection. When the user presses the push-button next to the correct selection, acknowledging the green lamp, the machine will then present the next question after the advance push-button is pressed. In this mode, a single error is permitted before the user is given the correct answer. This mode of operation may be useful for individuals who are either mentally disabled or who are easily confused by the operation of the machine. It also seems that this mode of operation addresses the concern expressed by Pressey (1926) over exposing an individual repeatedly to incorrect information.

In *single-try* mode, the user is permitted to respond to each question only once before the question advance push-button must be pressed. If the selection made is correct, then the green lamp next to it is illuminated, while an incorrect selection will result in the buzzer sounding or illumination of the red lamp. No additional feedback is provided.

When set to *practice* mode, the operation of the machine is similar to that in the single-error-permitted mode. In practice mode, however, no coaching is given when an incorrect selection is made. In this mode, each press of a push-button representing an incorrect selection will result in either the buzzer sounding or illumination of the red lamp. The next question may be attempted only when the correct answer is found to the current question. In this mode, the machine seems to embody Thorndike's (1912) idea that progress should not be allowed until what is presented initially is contended with in the intended manner. This approach may frustrate the user, since there are 20 choices and considerable time may be spent trying to find the correct answer if the user either does not understand the question. Moreover, if the user is mentally impaired, then frustration might result sooner, since the user might not be able to recall which choices have already been selected.

The concern of frustrating the user seems to be contended with in the *paced-practice* mode. In this mode, the duration that each question is displayed is controlled by a timer. Briggs (1958) also reports that the timer may be used in conjunction with the other modes of operation already mentioned.

The final mode of operation is called *test* mode. Prepared in this manner, the subject matter trainer functions similar to Pressey's testing/teaching machines set in testing mode. Electro-mechanical counters in the subject matter trainer permit the device to record both the number of correct and incorrect responses made (Briggs, 1958).

Lumsdaine (1959) reports that approximately 6 examples of the subject matter trainer were manufactured. Briggs (1958) states that the machines were manufactured by the Hathaway Instrument Company under contract to the Air Force. It is likely, given the complexity of the mechanism, that the subject matter trainer is an expensive teaching machine. This view is shared by Lumsdaine (1959) who adds that such a high cost is, "very minor in relation to the total training cost for technicians who used it" (p. 166). There is no evidence to indicate that the subject matter trainer was modified for commercial production and sale. The ergonomic problem of having the user stand to use the subject matter trainer appears to have been considered by Briggs, since he devised another teaching machine that is designed to be used when the subject is seated.

Brigg's card-sort device

Briggs designed a teaching machine that combines some of the electro-mechanical elements of the subject matter trainer with the individual item presentation feature of the pre 1928 versions of Pressey's testing/teaching machines. Called the *card-sort device*, the apparatus consists of a housing that is intended to be placed on top of a desk or table (Briggs, 1958). The housing contains a variety of electric circuits, electro-mechanical mechanisms and provision for up to 100 cards printed with information and/or questions. By means of the electro-mechanical mechanisms, each card is displayed to the user in succession through a viewing window in the front of the housing. Four push-button keys, similar in nature to the keys of Pressey's testing/teaching machines, are located below the viewing window. A panel containing two rows of lamps is located between the viewing window and the keys. The upper row consists of four red lamps, while the lower row contains four green lamps. Foltz (1961) claims that the lamps facilitate the use of the apparatus by individuals who are colour blind. While he claims that the lamps of different colours are distinguishable by each having a different shape, no such variation in shape is visible in photographs of the apparatus. It is likely that the position of the lamps is what enables colour blind individuals to distinguish the significance of each lamp. The lamps are arranged like traffic signals, with the red lamps uppermost and the green lamps below. Like the subject matter trainer, the card-sort device can also be set to perform in several modes. A key operated switch prevents unauthorized use of the machine. Figure 66 (after photographs in Briggs, 1958, p. 674; Lumsdaine & Glaser, 1960, p. 303 and drawing in Stolurow, 1961, p. 24) shows a general view of Briggs' card-sort device with the lid of the housing removed to show some of the internal arrangements.

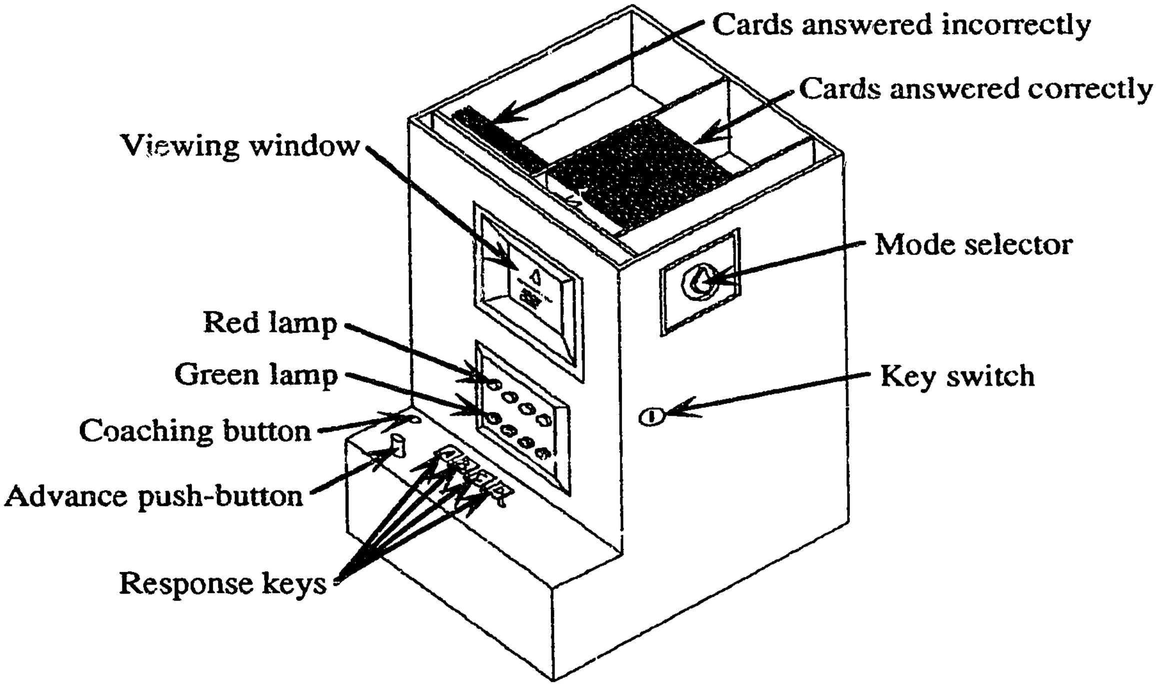


Figure 66. General appearance of Briggs' card-sort device with lid removed

The operating principle of the card-sort device is similar to that of the subject matter trainer, except that the card-sort device possesses only four operating modes (Briggs, 1958). An edge of each card is notched so that particular micro switches are either closed or open when the card is placed next to the viewing window. Once a card is in place next to the viewing window, the machine is prepared to accept input from the user. This is done by the user pressing one of the four keys. If the correct key is pressed, then the green lamp located above that key is illuminated. The user then presses the advance push-button and the card is moved into the right-hand bin near the top of the machine, and the next card in the series is moved up to the viewing window. A variety of actions can occur when an incorrect key is pressed, depending upon which mode of operation is used. In certain instances, the red lamp above the key pressed will be illuminated, indicating that another selection must be made. The red lamp remains illuminated until the next choice is made, to preclude the user from making the same mistake again. If the user has no idea which response is correct, then the coaching button may be moved and the machine will indicate the correct response. In another mode, the red lamp above the incorrect selection will be illuminated and the card will be moved into the left-hand bin in the top of the machine. Each card answered incorrectly is similarly moved into this bin. When all of the cards in the sequence are answered, then the machine moves each of the cards answered incorrectly back in front of the viewing window. This process continues until all of the cards are answered correctly (Briggs, 1958). Briggs (1959) reports that after a card sequence is completed, the machine may be set so that the user will be presented with a mixture of cards answered incorrectly and cards answered correctly.

A similar machine was constructed for the United States Navy. Called the *green light rater*, the device can hold up to 42 cards and can be prepared to accommodate questions with up to six distractors (Foltz, 1961). It seems that the green light rater was superseded by Briggs' card sort device, since Foltz (1961) notes that the Navy was using the green light rater only experimentally.

While it appears that Briggs developed an electro-mechanical version of Pressey's testing/teaching machines, the card-sort device is more complex than any of Pressey's devices and is probably more expensive. It does not seem that either the military or any commercial firm found the card-sort device to be satisfactory for mass production. It is likely that cost, maintenance and the existence of simpler teaching machines were factors that contributed to the limited deployment both of the subject matter trainer and the card-sort device. Although Briggs' electro-mechanical teaching machines were not adapted and developed for the educational market, several similar devices were developed and marketed by others during the teaching machine boom of the 1960s. Most of the commercial machines are able to function in one mode only and are also simpler in construction and smaller in size.

Drillmaster

Initially marketed as the *omnibox teachall* by U. S. Photo Supply, manufacture of the device under the name *drillmaster* continued into the early 1970s by the Teachall Corporation. Smaller than Briggs' card sorter, the drillmaster consists of a plastic housing containing two bins that can hold a number of cards. Each card is moved in front of a viewing window by sliding a lever to the left. Five keys permit each question to have up to five distractors. Each card is notched at one point along the bottom. The notch signifies to the mechanism which choice is correct by completing part of an electric circuit. If the correct key is pressed the electric circuit is completed, a green lamp will glow, a buzzer will sound and the card will be dropped from the viewing window (Hendershot, 1964; 1967). Finn and Perrin (1962) claim that a bell is used rather than a buzzer. It may be that initial versions used a bell, while later versions used a buzzer. A paucity of examples precludes resolving this point. All sources agree that power for the lamp and the auditory signal is supplied by a 1.5 V, C-cell battery. The use of a battery for the power supply means that the drillmaster is more easily transported than any of the larger electro-mechanical devices mentioned previously. The drillmaster may also be used in locations where electricity is not available, an important consideration for schools located in isolated and remote areas.

The auditory and visual signals indicate to the user that the next card may be moved into position. An incorrect key press does not result in any action by the machine. The drillmaster functions in a similar manner to Pressey's pre 1928 model testing/teaching machines set in teaching mode. Unlike Pressey's models, or some of Briggs' electro-mechanical devices, the drillmaster has no provision to record either the number of key presses or the number of incorrect selections. Prepared programs may be used with the drillmaster. In 1965, nine different programs were available (Gille, 1965). The content appears to be primarily at an elementary level. It is likely that individuals could also purchase blank cards and design their own programs.

Sales of the drillmaster were likely sufficient to keep it in production for several years. The price of this teaching machine in American funds, ranged from $34.75 in 1964, to $49.50 in 1967 (Hendershot, 1964; 1967). Gille (1965) reports that schools could obtain units at discount prices. It is not known where the greatest sales were concentrated, or even how many units were actually sold. Production of the drillmaster probably ceased during the early 1970s, since no trace of the company can be found beyond this time.

Although the drillmaster seems to be derived ultimately from Pressey's testing/teaching machines, and was marketed during a time of economic prosperity and during a period where schools were encouraged to use teaching machines, the drillmaster failed to gain enough acceptance to sustain its sales. As with most other instructional devices described to this point, the drillmaster was comparatively short-lived. While it may be argued that the pedagogical method of the drillmaster and its theoretical basis may be superior to more traditional theories and approaches, other factors such as competition by other teaching machines impinged upon the drillmaster.

Miesegaes' question and answer device

A skill that is especially important for some military personnel is aircraft identification. The shortage of trainers in the American military during the Second World War has been noted in previous sections. During the Second World War, William Miesegaes designed a teaching machine for aircraft identification, intended to reduce the instructional time required with a human instructor and to provide additional information and training. Named the *question and answer device*, the apparatus consists of a housing containing a viewing lens and a means of holding and displaying a 35 mm film strip. A mechanism controlled by an external plunger permits the user not only to advance the film strip a set increment, but also to move a mask that obscures a part of the film strip. Figure 67 (after drawing in United States Patent Number 2,394,711, February 12, 1946) shows the external appearance of Miesegaes' question and answer device. It should be noted that an aperture in the housing, aligned with the viewing lens and which permits light to pass through the film is not visible in the drawing.

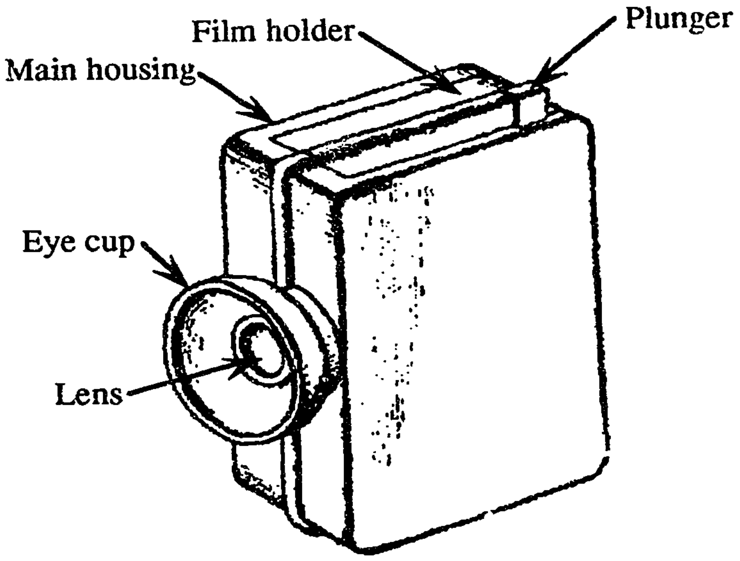


Figure 67. External appearance of Miesegaes' question and answer device

To use the device, a prepared filmstrip is loaded into the film holder and the assembly is held towards a light source. The user places the eye cup up to an eye then depresses and releases the plunger repeatedly until the first image becomes visible. The mechanism controlling the film ensures that the image is framed in a particular way, so that information near the bottom edge of the image area is obscured by a moveable opaque mask.

Figure 68 (after drawing in United States Patent Number 2,394,711, February 12, 1946) shows a portion of a filmstrip and the usual position of the mask.

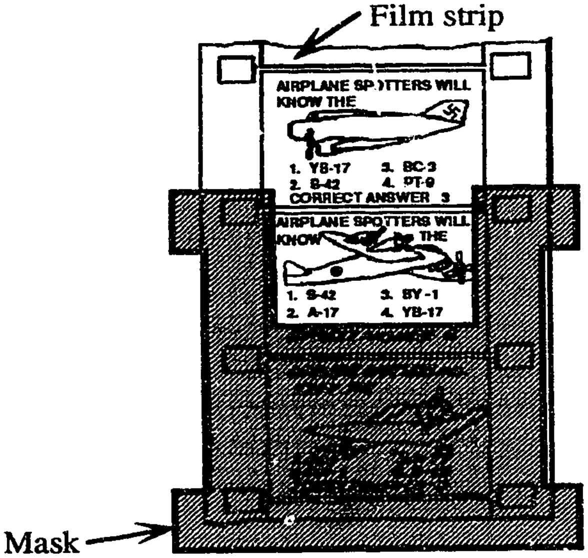


Figure 68. Arrangement of mask in Miesegaes' question and answer device

The user answers the question either by writing down the selection, or by choosing a response mentally. Once a choice is made, the plunger is depressed again. This action causes the mask to be moved downwards, revealing the correct answer. Releasing the plunger returns the mask to its normal position as well as causing a sprocket mechanism to advance the filmstrip so that the next question is displayed (United Sates Patent Number 2,394,711, February 12, 1946). In this manner, the machine presents information, accepts and transforms user input, and provides instructive feedback based on the transformation of the input. It might seem that this arrangement disqualifies the question and answer device as a teaching machine, since the transformation of the user input is the same no matter what information is presented to the user. As well, any instructive feedback is entirely dependent upon the user, both to recall the choice made and to compare that choice with the correct answer. The device is a teaching machine, however, since the instructive feedback is presented to the user only after the question is read and a selection of an answer is made; instructive feedback is dependent upon input by the user and the transformation of that input. While it is possible to cheat using the question and answer device, it is important to note that the operating principle of Miesegaes' teaching machine is similar to that found in one type of teaching machine devised by B. F. Skinner in the late 1950s. Skinner's teaching machines are described in a subsequent section.

The design of Miesegaes' question and answer device is not new. A stereoscopic, home-entertainment device known as the Sawyer's *Viewmaster* was marketed several years before Miesegaes patented his apparatus. The Viewmaster, however, was not designed as a teaching machine, nor did it obscure a portion of the image and then reveal it in response to user input. Unlike the Viewmaster, it does not appear that Miesegaes' question and answer device was popular either in the military or in civilian education as a teaching machine. Simpler devices that obscure the correct answer until there is user input, were designed both within the military and outside it.

Tab Items

The rapid and successful training of maintenance technicians became a priority within the American military by the time of the Korean War. Equipment to be used for training purposes could not usually be spared, so there was a need for some means of providing practice to maintenance technicians without the necessity of having them learn on the actual equipment (Fry, Bryan & Rigney, 1960). The nature of some equipment, radar sets for example, is such that mistakes made in practice may cause irreparable damage to the apparatus (Glaser, Damrin & Gardner, 1954). While mechanical simulators existed at that time (Gagné, 1954) most were intended for training combat personnel. As well, the simulators themselves are expensive and they too require maintenance, sometimes more exacting maintenance than the actual equipment they simulate (Kelly & Parke, 1970). A simpler means of practice was required for technicians, therefore. As well as being simple, the means of practice should: not interfere with combat equipment and other essential or expensive apparatus; be unlikely to require special maintenance and should pose a minimal safety hazard to the learner. Lumsdaine (1959) reports that a special type of narrated sound film and small projection system was used experimentally to teach technicians specific procedures. This device is a teaching aid, since there is no provision for user input and, therefore, no instructional feedback. While Lumsdaine (1959) states that the tests with the apparatus were considered successful, it is important to note that a linear type of *repair-by-number* approach was used. An example of this method might be, "Step 1, grasp the top of light bulb A with right hand. Step 2, locate socket B. Step 3, insert the base of light bulb A into socket B. Step 4, rotate light bulb A clockwise in socket B". While this approach may be suitable for individuals who are already familiar with the process, it may confuse those who have no psychomotor experience with that particular skill, or those who are not familiar with the parts named. This type of linear approach also makes no provision for mistakes by the user or for unforeseen circumstances, such as the base of light bulb A being too big to fit into socket B.

Considering such factors, personnel in the United States Air Force designed a system of practice that does not use the actual equipment, but which informs the user of the consequences of each action made. The apparatus, designed by 1954, is referred to variously as a *tab item*, *tab item device*, *tab test device*, or as the *pull-tab* (Fry, Bryan & Rigney, 1960; Stolurow, 1961). In this account, the term *tab item* will be used. In most cases, tab items comprise several pages and they consist of printed information and cardboard tabs that are either stapled or glued loosely onto specific areas of the pages (Glaser, Damrin & Gardner, 1954; Fry, Bryan & Rigney, 1960).

One of the first uses of the tab item design was to teach trouble-shooting techniques to electronic technicians in the United States Air Force. In most instances, the top of the first page is printed with a particular problem or condition of the apparatus. This is followed by a listing of possible defective parts or circuits and various illustrations of parts and diagnostic displays. Next to these items are cardboard tabs that cover information or illustrations. The user is supposed to treat the problem by selecting parts and diagnostic strategies from the sheets and pulling the tabs next to the items as they are selected. When a tab is pulled off, information printed underneath will be revealed to the user. The message will indicate that the step chosen is either correct or incorrect. After selecting an incorrect step or procedure, it is anticipated that the user will go back to the last correct choice and then select another course of action. The user continues in this manner until the final tab is removed, thus informing the user that the problem has been solved correctly. The number of tabs pulled is used as an indication of efficiency, since proficient technicians will usually make fewer errors and, therefore, have fewer tabs at the end of the procedure (Fry, Bryan & Rigney, 1960). A similar type of tab item, called the *optimum sequence trainer*, was developed for the United States Navy subsequent to the development of the tab item for the Air Force (Foltz, 1961).

The idea of providing additional information to individuals who removed an incorrect tab appears to have occurred to some individuals involved with the initial design of the tab item exercises. Fry, Bryan and Rigney (1960) describe an experimental study done with tab items, where experimental groups received short verbal explanations whenever an incorrect tab was removed. The findings indicate that providing additional feedback improved subject performance and retention of information.

Glaser, Damrin and Gardner (1954) suggest that the tab item itself may be designed to provide additional feedback. Instead of each tab covering an indication of whether the choice is correct or incorrect, it is proposed that each selection be ranked in some manner, so that each choice be given an indication of relevance to the diagnostic procedure. In this case, when each tab is pulled off, one of the following words will be visible: relevant, additional, redundant, inadequate, irrelevant (Glaser, Damrin & Gardner, 1954). Through this arrangement, the user gains some knowledge of how appropriate or inappropriate a particular selection is to the diagnostic procedure.

It is likely that these findings influenced the way some subsequent apparatus was designed. For example, Norman Crowder, who was involved with the development of tab items, designed a version that provides remedial feedback when an incorrect tab is removed (Foltz, 1961). Developing this idea further, Crowder later developed programmed textbooks, sometimes called *scrambled books*, which provide remedial information when an incorrect choice is made (Fry, Bryan & Rigney, 1960). Crowder also developed a type of teaching machine that provides remedial information whenever an incorrect choice is made (Crowder, 1959; 1960). These developments are described and discussed in subsequent sections.

Tab item exercises are similar in principle to the envelope test devised by LaZerte (1933). The use of tab items as tests seems to have occurred to many individuals, however (Fry Bryan and Rigney, 1960). While tab item exercises may be used as tests of diagnostic ability, they may also be designed to function in a similar manner to Pressey's punchboard. At least one type of tab item of this variety was marketed commercially.

Nelson's multi-purpose self trainer

This version of the tab item was first published in 1954 by Charles W. Nelson, and marketed under the name of *multi-purpose self trainer* (Fry, Bryan & Rigney, 1960; Finn & Perrin, 1962). Fry, Bryan and Rigney (1960) state that the device is also known as the *pluck-card*. Nelson's multi-purpose self trainer consists of an answer card that is overlain with a thinner paper or cardboard covering that is punched so that individual removable tabs are formed. This overlay is also printed with either 10 or 24 rows of multiple-choice responses. Each row contains 5 possible selections (Finn & Perrin, 1962). The tabs covering the selections are marked with letters. The letters used are a, b, c, d. Letters are also printed underneath the tabs. The letters used here are A, K, Q, J, T. These letters stand for the names of playing cards, specifically Ace, King, Queen, Jack and Ten (Fry, Bryan & Rigney, 1960). Fry (1963) claims that Nelson uses these letters because playing cards are likely to be familiar to most students and, consequently, student interest will be sustained. By using symbols that are associated with a particular hierarchy, it is also possible to construct tests with questions that have more than one correct answer, with different number of points awarded to the different answer choices (Fry, Bryan & Rigney, 1960).

The multi-purpose self trainer cards are used in a manner similar to punchboards. The questions are presented on a separate sheet and the user registers the answers on the self trainer card by pulling off the tabs corresponding to the choice considered to be correct. Unlike punchboards the multi-purpose self trainer cards provide the user with more feedback than a simple indication of whether the choice is correct or incorrect. If a user should remove a tab that reveals an A, signifying an Ace, then the user is also informed that there is no better response. Similarly, if a tab is pulled that reveals a K, for

King, then the user is aware that there is another choice considered to be better, and the user is expected to keep making selections until the A is found. In this manner, the user gains some knowledge of how appropriate each selection is to the answer (Fry, Bryan & Rigney, 1960).

The cards designed for recording selections made to true-false tests also contain five choices for each question. Instead of the tabs covering letters signifying playing cards, the tabs cover a series of the letter *o* and a single letter *x*. The letter x represents the selection that is true, while each letter o represents a false selection (Gille, 1965). Through comparison, the user may learn which statement is true and which is false, if the correct answer is not known immediately. The design of the card also permits the examiner to design a true-false test where the score is equal to the number of right responses minus the number of incorrect tries (Gille, 1965). The similarity between Nelson's multi-purpose self trainer cards and punchboards is not coincidental. Fry, Bryan & Rigney (1960) report that Nelson designed his cards from knowledge of Angell's and Troyer's punchboard.

Multi-purpose self trainer cards were marketed by Management Research Associates, a company operated by Nelson. The prices of cards, in United States funds, were 10¢ each for the 10-responses cards and 20¢ each for the 24-responses cards. A sixty-item true/false card also sold for 20¢ apiece. An additional expense was a $2.75 manual that is essential to use the cards, since one must know how the correct responses are keyed on the cards (Hendershot, 1969). Nelson's multi-purpose self trainer cards were marketed for several years, and it is likely that production of them has ceased, since no record of the company can be found. Tab-type apparatus was not the only attempt at designing a teaching machine without mechanical or electrical apparatus.

Buitenkand's overlay trainer-tester

The use of erasable overlays has been mentioned previously in the section on Pressey's erasable overlay card. It seems that the idea of using an erasable ink to obscure instructive feedback was developed by Nathan Buitenkand by 1953, when he applied for a patent on a method of training in trouble-shooting techniques using cards overprinted with an erasable ink (United States Patent Number 2,764,821, October 2, 1956). By the time the patent was awarded in 1956, the rights were assigned to the commercial firm Van Valkenburgh, Nooger, and Neville (Fry, Bryan & Rigney, 1960). Marketed under the name *trainer-tester* as a *non-hardware teaching machine* (Foltz, 1961) the cards are laid out similar to some tab items. One version, intended to provide training in trouble-shooting a superheterodyne receiver, contains a printed indication of a problem or malfunction in the circuit. A number of solutions are also given as well as particular diagnostic tests. The user is instructed to erase the silver-coloured overlays next to the strategies thought to be appropriate. Erasure of the overlays provides the user with information about what the strategy will do and whether or not it is appropriate in solving the particular problem (Fry, Bryan & Rigney, 1960). Several versions of trainer-tester cards were available, including ones consisting of wiring diagrams and schematics and others that simulate experiments in chemistry and other laboratory subjects (Finn & Perrin, 1962; Fry, 1963). The cost of the trainer-tester sheets was comparable to tab item cards. Hendershot (1964) reports that each trainer-tester card cost 10¢ American in 1964. It is not known when this type of erasable overlay card was discontinued. Erasable overlays continue to be used in some games and promotional items.

While the trainer-tester sheets as well as tab items can function as teaching machines, these devices are also rudimentary simulators. Like the quintain, overlay-type teaching machines endeavor to reproduce elements of a particular situation. In the case of the quintain, elements of a military opponent are simulated. Overlay-type teaching machines usually simulate aspects of actual equipment or laboratory experiments. Possible reasons for using simulations of an object or a situation include cost, low availability of the actual object or situation, danger to the user if mistakes are made and a risk of damage to the equipment. While some individuals claim that teaching machines endeavor to simulate a teacher (Skinner, 1958; Kneller, 1962; Keller, 1968) devices that truly simulate aspects of an actual object or a situation have evolved into a separate category of teaching machines intended for specialized forms of instruction both within the military and in civilian applications. Simulators are described and discussed in Chapter VIII.

While some teaching machines developed for military applications and adapted for school use were marketed with some success, the devices that gained the greatest attention of educators before the mid 1960s were the teaching machines either developed by B. F. Skinner, or those based on his principles of behaviorism.

Teaching machines based on behaviorism

Behaviorism as applied to pedagogy

B. F. Skinner (1904-1990) did not develop his teaching machines based on personal experience as an educator. Skinner's initial interest in psychology was based largely on the theories of John B. Watson (1878-1958) (Skinner, 1976; 1983). Watsonian behaviorism, first postulated in 1912, is a theory concerned primarily with the behavior of organisms that is both visible and quantifiable, and which also can be demonstrated to be elicited by external stimuli recognizable to the senses (Watson, 1928; 1930). This variety of theoretical approach is sometimes referred to as a "black box approach" (Bourne & Ekstrand, 1976). Such theories acknowledge that something occurs within the brain or *mind*, but since we do not have the means to observe and measure these actions, it is useless and unscientific to speculate on the rôle of the brain or mind. Watson, like Thorndike and the Russian Pavlov, found that behavior of animals and human beings could be modified or *conditioned* through the pairing of neutral stimuli with stimuli known to elicit particular behaviors. In an experiment with a young male child, for example, Watson and Rayner (1920) found that they could condition or *teach* the child to fear white rats and other furry objects by combining these stimuli with a noxious stimulus, a loud noise. Such replicable experimental findings led Watson to conclude that it is contingencies within the environment that comprise the main factors that determine behavior and, therefore, what is learned. Watson (1930) goes further and states,

> Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I'll guarantee to take any one at random and train him to become any type of specialist I might select... regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors. (p. 104)

There is no evidence that Watson attempted to put this theory into practice, but Bugelski (1971) claims that Watson did suggest some practical modifications to the environment to facilitate learning such as the fabrication of piano keyboards with narrow keys for individuals with small hands. While Watson may have considered this idea novel, musicians such as the pianist Sergei Rachmaninov had been using modified keyboards as well as other modified instruments to accommodate personal differences.

Teaching machines based on Watsonian behaviorism

Although Watson did not take an active rôle in the development of teaching machines, there are some instructional devices that embody Watsonian behaviorism. Examples include the various contrivances designed to *condition* or teach children to cease bed-wetting, referred to as *enuresis*. Most children who learn to control their bladders, associate bladder distention with the imminent need of urinating. This association exists during sleep as well, so if bladder distention is experienced, then the individual wakes up in time to urinate in an appropriate location. In some instances, not including individuals with infections, muscle dysfunction or diseases, the stimulus of bladder distention is not associated with waking up. The result is a wet bed. Mowrer and Mowrer (1938) note many attempts at treating enuresis through physical and medical means are usually unsuccessful, since they contend that in at least 95% of cases the causes are psychological rather than physiological. The authors describe how some primitive peoples allow their children to sleep with their parents. In many instances, when a child urinates while sleeping, a parent sensing the urine will react by waking the child and moving it away from the bed or sleeping area. This action usually results in the child ultimately learning not to urinate while in bed. Mowrer and Mowrer (1938) claim that it is the parents' immediate response to the onset of the child's urination, and the consequent association by the child of urination with waking up, that results in the child learning to control urination while sleeping. Considering such anecdotal evidence and social traditions of western cultures discouraging children sleeping with their parents, Mowrer and Mowrer (1938) postulate that a child exhibiting enuresis can be taught nocturnal bladder control by means of a machine constructed according to the principles of Watsonian behaviorism.

In designing the apparatus, Mowrer and Mowrer (1938) state that the machine should not interfere with the child's movement while sleeping, and should not harm or scare the child. Considering the conductive properties of urine, Mowrer and Mowrer (1938) designed a pad containing two pieces of bronze screening measuring approximately 28 by 32 inches (711 mm X 813 mm) located between three layers of cotton cloth. A wire is soldered to each piece of screening. The other ends of the wires are connected in series with a radio dry cell battery and a relay. The battery is also connected to another series circuit containing the relay, a rheostat and an electric door bell. The battery and the other electrical components are housed in a small metal box.

The pad assembly is placed on the lower part of the bed, so that the pelvis of the child is normally resting on the pad. If the child begins to urinate while sleeping, then the urine saturates the cloth pieces of the pad. The urine completes the circuit to the relay. Activating the relay closes the circuit to the bell. The sound of the bell is usually sufficient to wake the child. If it is found that the bell is too loud, so that the child is scared, then the rheostat may be adjusted to diminish the sound (Mowrer & Mowrer, 1938). While Mowrer and Mowrer (1938) report that the use of the pad results in most children soon associating onset of urination with waking up, the authors note that the pad may be activated unintentionally by nocturnal emissions of adolescent boys. The authors also note that no empirical evidence is available to indicate whether activation of the device in such instances result in any *untoward consequences*.

Similar apparatus is available commercially at the present time. One example, marketed by Sears, Roebuck and Company, is called *Wee-alert*. While largely similar to the apparatus designed by Mowrer and Mowrer (1938) a sheet comprised of two thin, perforated metal layers separated by a layer of porous cloth is used rather than the bronze screening sandwich. A buzzer is used in the Wee-alert instead of a bell. Bourne and Ekstrand (1976) report that the Wee-alert is also effective in treating enuresis after a few pairings of the buzzer with the onset of the problem. The authors also report the existence of similar apparatus contained in diapers and training pants, to teach toilet training to children. These devices do function as teaching machines, since they accept input from the user, perform a transformation of it and then provide instructive feedback.

Bourne and Ekstrand (1976) note that the success of this type of teaching machine has prompted some enterprises to market expensive versions that function identically to less expensive models. The authors contend that this variety of commercialism is questionable, since it attempts to sell the product by capitalizing, "on the fears of parents" (p. 136). It is likely that this sort of marketing strategy is eventually deleterious to the sales of such devices, since parents may conclude that the cost of the apparatus is too high.

The factor of commercialism not only impinges upon apparatus already in production, but it may also determine whether or not an instructional device is manufactured or not.

B. F. Skinner's teaching machines

Introduction

Although Skinner agrees with Watson's basic premise, that it is contingencies of environment that determine behavior and learning, Skinner's position is not as extreme. Skinner also identified a method of conditioning different from those used by Thorndike, Pavlov and Watson. Called *operant conditioning*, this method is not concerned primarily with an initial stimulus, but with the consequences of a particular behavior. *Reinforcement* is considered to be any consequence that is likely to lead to reoccurrence of the behavior it follows, while *punishment* is intended to discourage repetition of that behavior. Skinner (1971) also finds punishment to be largely ineffective, so he does not advocate its use. Most of Skinner's findings are based on experiments with animals, including his work in the Second World War, where he designed a missile guidance system controlled by pigeons (Skinner, 1979). The application of Skinner's theories to learning in human beings did not occur until after he observed how one of his daughter's classes was being taught one day. During the visit, Skinner noted that the entire class received an assignment and a set amount of time to complete it. He observed that some individuals finished quickly and were soon bored, while others could not finish in the time provided. Once the time had expired, the assignments were collected for grading, not to be returned to the students until the next day at least. Skinner (1983) states,

> I suddenly realized that something had to be done... the teacher was violating two fundamental principles: the students were not being told at once whether their work was right or wrong (a corrected paper seen twenty-four hours later could not act as a reinforcer), and they were all moving at the same pace regardless of preparation or ability. (p. 64)

Adapting his experience with training animals, Skinner later devised several types of teaching machines based on his theories of behaviorism. Skinner (1983) states that he had devised a teaching machine based on his theory of learning as early as 1950. Although this device was not actually constructed, a representation of it was used as a prop in a school play written by Skinner (Skinner, 1983).

While one may argue that the findings obtained from experiments with animals are applicable to human beings because they are animals as well, it may also be argued that comparisons of this sort are invalid because they ignore factors such as species-specific behavior and differences between species. Ethologists such as Konrad Lorenz, contend that such *black box theories*, especially behaviorism which appears to downplay the differences between species, present an incomplete picture of behavior at best, or lead to major fallacies at worst (Lorenz, 1971; 1981). Skinner, as well as some educators, have dismissed such criticism as being *unscientific* (Skinner, 1983). Moreover, Mueller (1987) contends that, "the logic and empirical evidence for programmed instruction were — and still are — virtually unassailable" (p. 414). While such statements are probably reinforcing to behaviorists, they ignore evidence to the contrary. One of Skinner's graduate students, Keller Breland, later ran a business that trained circus animals using methods derived from Skinnerian behaviorism. While the behavior of the animals was altered by the methods of training, some animals later reverted to *instinctive* behavior, and no amount of retraining would undo this tendency to instinctive behavior (Breland & Breland, 1961). Similarly, the ultimate failure of teaching machines based on Skinnerian behaviorism to gain widespread use is explained simply by Skinner (1986) that, "Teachers misunderstood the role of teaching machines and were fearful of losing their jobs" (p. 105). While fear of unemployment may have been one factor, there were other factors that impinged upon the deployment and the development of teaching machines. Skinner himself notes some of these factors elsewhere (Skinner, 1983).

Skinner's design for teaching machines was not derived from the study of earlier innovations and developments in education, even though Skinner's contention that immediate knowledge of test results is beneficial to learning is a similar observation to one made by Pressey many years earlier. Skinner (1983) states that he did not know of the earlier work of Pressey. It is also likely that Skinner was not aware of other antecedent teaching machines and teaching aids, since he appears to dismiss the study of history entirely. Skinner (1983) states, "History was like developmentalism in psychology. One could identify patterns, cycles, and sequences... but, once identified, nothing could be done about them or with them" (p. 176). Skinner was convinced for a time that his invention of a teaching machine was a new innovation in education (Skinner, 1954). It will be shown that his ignorance of the historical development of instructional devices ensured that Skinner's devices were as susceptible to many unforeseen factors, as were Pressey's testing/teaching machines. Although Skinner later attempted to connect the development of his teaching machines with earlier educational innovations and theories (Skinner, 1961b) the process was done retroactively, not proactively. It may be argued that if Skinner had been aware of earlier developments and had applied them to his own innovations before he released them publicly, then the propagation and deployment of his teaching machines might have been more successful and effective than they were.

Slider-type teaching machines

A few days after observing his daughter's class, Skinner constructed a teaching machine. The apparatus used cards that had problems in arithmetic printed on them. A hole was punched through each card, but each hole was placed at a different location in each card. The cards were placed in a housing also containing two sliders, probably small rods or bars, that already had small pieces of card attached to them. These cards were printed with single numerals. To use the apparatus, a card must be placed next to the sliders as directed, then the sliders are moved to compose a two digit number which comprises the response. Constructing the correct response results in the hole through the card being uncovered so that light is visible through it. The light is feedback to the user that the response is correct (Skinner, 1983). The first prototype possesses many limitations including requiring the user to install each question card, being restricted to a one or a two digit response, and no means of preventing cheating. Skinner recognized these limitations and designed improved prototypes.

In the next version, Skinner installed a mechanism that prevented the machine from providing feedback to the user until a button was pressed that moved a lever. The lever controls two mechanisms. The first holds the sliders in position. The second uncovers a row of holes that allow light to be visible if the response is correct (Skinner, 1983). No light indicates that an incorrect response has been constructed. With these mechanisms, the teaching machine prevents the user from finding the correct response by moving the sliders up and down indiscriminately until light is visible in the feedback holes. The problems of question presentation and limited answer size were addressed in subsequent prototypes.

To eliminate the necessity of placing question cards in the machine, Skinner devised a mechanism of rollers that could move either a roll of paper or a pleated array of cards past a viewing window. Motive power for the rollers is provided by the user through a crank or knob. The roller and drive assembly as well as an array of four sliders, are enclosed in a plywood housing. This prototype was completed by 1954 (Skinner, 1954). Figure 69 (after photograph in Epstein & Epstein, 1961, p. 8, and description in Skinner, 1954; 1983) shows the general appearance of Skinner's third prototype slider teaching machine. External details not essential to the machine's operation, such as screw heads and hinges, are omitted.

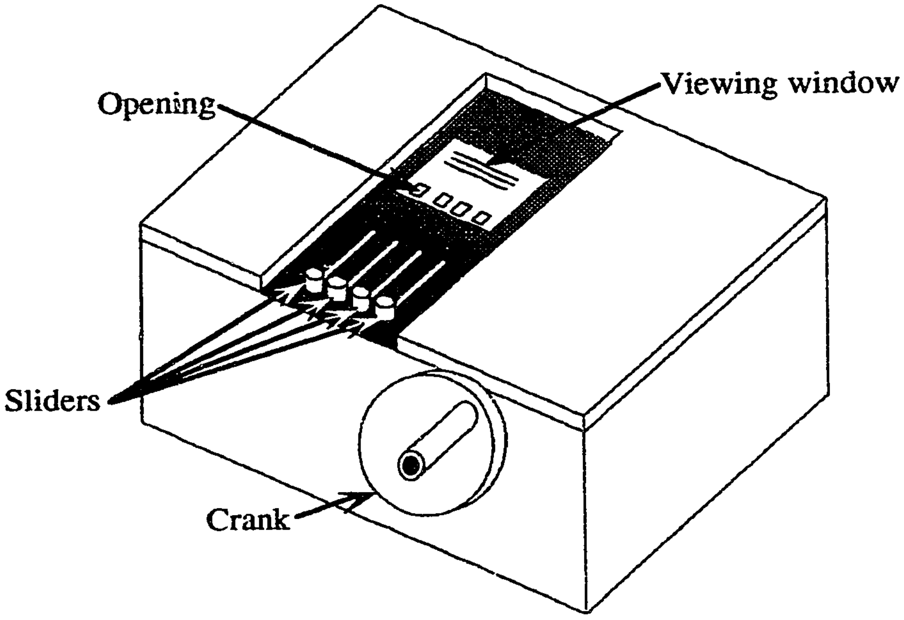


Figure 69. Appearance of Skinner's third prototype slider teaching machine

The operation of this prototype follows the same principles as earlier models. Through turning the crank, each question is aligned in the viewing window. The sliders are moved to construct a response in the four openings. Once the response is constructed, the user attempts to turn the crank again. If the response is correct, then the crank will be permitted to move. Turning the crank causes the roll to move, thus bringing the next question into view. Skinner (1954) adds that this manœuvre, "cannot be completed, however, until the sliders have been returned to zero" (p. 95). Skinner (1954) also notes that a bell or a similar signal can be made to ring when each question is answered correctly. Constructing an incorrect response causes the mechanism to lock the crank so that it will not turn, thus indicating to the user that the response is wrong. By reversing the crank slightly, the user is able to reset the sliders and try again (Skinner, 1954). It appears that more than one prototype of this design was fabricated by Skinner, since another photograph shows a machine with six sliders and a knob without a handle (Skinner, 1986, p. 104). Although Skinner does not describe the mechanical aspects of his slider-type teaching machines, it seems from his descriptions that the sliders work in conjunction with some variety of spring-loaded sensors, such as wire loops, that pass through holes in the question rolls that are obscured from view. Like a lock, or like LaZerte's problem cylinder, when the correct combination of slider positions is made, the movement of the sensors through holes in the question roll cause the feed mechanism to be engaged, thus permitting the roll to be advanced.

Like Pressey, Skinner (1983) contends that if teaching machines are to gain widespread use in schools, then they must be marketed commercially. Through contacts with alumni of Harvard University, Skinner's slider-type teaching machine received attention from the electric typewriter division of IBM by the end of 1954 (Skinner, 1983). Skinner and at least one of his graduate students wrote programs for the slider-type teaching machine. Program subjects included spelling and arithmetic (Skinner, 1983). IBM did not share Skinner's enthusiasm for his slider-type teaching machines, since it took IBM three years to prepare a plaster model of their version of the device. A working prototype was completed in 1957, soon after the completion of the plaster model (Skinner, 1983).

The operation of the IBM version of the slider-type teaching machine is similar in principle to the versions described previously. The appearance is different, however. The IBM prototype consists of a two-part housing. The user faces a long rhombus-shaped portion that contains 10 sliders along the upper surface as well as a hand crank located on the right-hand side. Printed cards containing the questions are located in a rectangular housing, mounted at an angle, on top of the rhombus-shaped portion (Skinner, 1986). While the movement of the hand crank resets the sliders, power to move the cards is provided by an electo-mechanical system powered by household voltage.

Skinner (1983) states that IBM requested a report on the effectiveness of the device and the optimal length of lessons, but that IBM was unwilling to provide him with more than one machine. Limited use of the single IBM prototype with a number of elementary school students was undertaken by one of Skinner's graduate students. Skinner (1983) reports that, "the children liked the machine and learned quickly" (p. 144). In spite of the positive findings from limited field testing, IBM decided to discontinue work on the slider machine by 1958, citing the need to concentrate its resources on developing their typewriters. Although other leads were followed, the slider-type teaching machine was not manufactured commercially (Skinner, 1983). Consideration of the apparatus by manufacturers was one factor that prevented his slider-type teaching machine from being manufactured commercially. It will be shown subsequently that it was not until Skinner attempted to market another type of teaching machine that he became aware that factors other than perceived pedagogical efficacy impinge upon the deployment of instructional devices.

Relationship to theories of learning

While it might appear that Skinner's slider-type teaching machines function in a manner similar to Pressey's testing/teaching machines, especially the feature of not presenting a new question until the current one is answered correctly, there are some notable differences. Skinner (1986) unlike Pressey, maintains that his machines are to be used by individuals who have not had any prior instruction in the subject matter presented by the machine. Unlike LaZerte (1933) Skinner does not seem to consider that the procedures and skills required to operate his teaching machine could add to the difficulty of the subject matter presented by the machine.

Skinner (1958) states that requiring composed answers tends to make the student recall information rather than to recognize it as with multiple-choice items. Moreover, Skinner (1958) maintains that multiple-choice distractors present erroneous but plausible choices that tend to interfere with the learning of the correct response. The theoretical bases of Pressey's and Skinner's machines reveal much greater differences.

While Pressey tended to follow the theories of Edward Thorndike, Skinner claims to have been guided primarily by his principles and tenets of behaviorism. Moreover, Skinner (1958) states that, "Pressey was working against a background of psychological theory which had not come to grips with the learning process... Rate of learning was observed, but little was done to change it" (p. 969). Skinner's contention appears to be both incomplete and erroneous in light of the work done by Thorndike, Judd and Montessori, and in respect to the work Pressey and others undertook with their teaching machines. The statement is also peculiar, since Skinner (1961b) later likens his teaching machines to the mechanical book envisaged by Thorndike in 1912 (see a previous section on Thorndike in this chapter).

A major component of Skinner's theory of behaviorism, as applied to learning in human beings, is the provision of what Skinner calls *positive reinforcement*. Positive reinforcement may be defined as a non-aversive consequence of a behavior or action, recognizable to the organism, which is intended to encourage a repetition of that action or behavior. Like Rousseau, Skinner (1983) contends, without citing supporting data, that aversive methods and punishment are the common means of behavior modification used by teachers. While he condemns the use of punishment like Rousseau and Thorndike, Skinner maintains that using consumable reinforcers such as letter-shaped cookies as advocated by Erasmus, are largely unnecessary, since intrinsic reinforcers such as obtaining the right answer are satisfactory (Skinner, 1961b; 1983). From his studies with animals, Skinner (1954) concludes that it is not necessary to provide reinforcement after every desired response, since a schedule of *intermittent reinforcement* is found to be superior both in teaching the organism and in maintaining that response. Skinner (1961b) contends that by reinforcing those behaviors that may not be deemed correct, but which indicate that the organism is exhibiting behaviors that are similar to the desired response, the behavior of the organism is gradually *shaped* or guided to the desired behavior by reinforcing *successive approximations*. Shaping the responses of human beings involves the reduction of complex skills and tasks into a number of simpler and smaller steps. Skinner (1958) states, "Each step must be so small that it can always be taken, yet in taking it the student moves somewhat closer to fully competent behavior" (p. 970). One method that Skinner devised to accomplish this type of shaping, is called *vanishing*.

Skinner (1983) states that he developed the method of vanishing or *fading* while he was attempting to teach one of his daughters a poem. The entire poem was first written on a blackboard. After his daughter had read it aloud, she was instructed to leave the room while Skinner erased a few letters from the poem. Upon her return, his daughter repeated the reading of the poem. The process of erasure and re-reading continued until there were no visual cues left at all, yet his daughter was able to recall the poem (Skinner, 1983). By first presenting the entire quantity of information and then gradually eliminating cues, Skinner contends that the individual is gradually taught recall of the information. Furthermore, Skinner (1983) reports that his daughter could recall the entire poem a month later. This finding suggests that information committed to memory in this manner is not stored as series of unrelated words, but as an array of words arranged according to a particular context.

While it is possible to design cards to enable the slider-type teaching machines to perform the vanishing of cues, the process is limited by the number of sliders present. Skinner overcame this limitation by designing other types of teaching machines.

Skinner's pocket-sized teaching machines

Immediately after discovering his technique of vanishing, Skinner (1983) states that he constructed several pocket-sized devices designed to hold a single card containing printed information to be learned. Sheets of frosted plastic or clear sheets marked with opaque areas are used to obscure information on the cards. As more sheets are placed on the device, more information is obscured. In this manner, these teaching machines are able to perform the vanishing of cues at the control of the user. It is likely that these teaching machines are similar in size and shape to Pressey's punchboard. This variety of teaching machine is limited by size and also by the honesty of the user, since it has no means of preventing an individual from cheating. Although Skinner did not develop his pocket-sized teaching machines further, the principles of vanishing and shaping were incorporated into another type of teaching machine that was designed to prevent cheating.

Skinner's disk-type teaching machines

While the slider-type teaching machine was being considered by IBM, Skinner developed another teaching machine that operates in an entirely different manner. This device consists of a rectangular box-like housing that contains a 12 inch diameter (305 mm) cardboard disk, printed with information, questions and answers. The housing also contains a roll of paper and a mechanical assembly. The top of the housing contains two viewing windows. The left-hand window permits segments of the disk to be visible. A moveable opaque shutter is located beneath the upper half of this window. The right-hand window permits the user to write on the paper strip. A transparent shutter is brought across this window at particular times. Figure 70 (after photograph and description in Skinner, 1958, p. 971; and drawing in Stolurow, 1961, p. 27) depicts an overhead view of Skinner's disk-type teaching machine with some internal components shown in phantom view. Note that not all of the segments are shown on the disk and that most mechanical details are omitted.

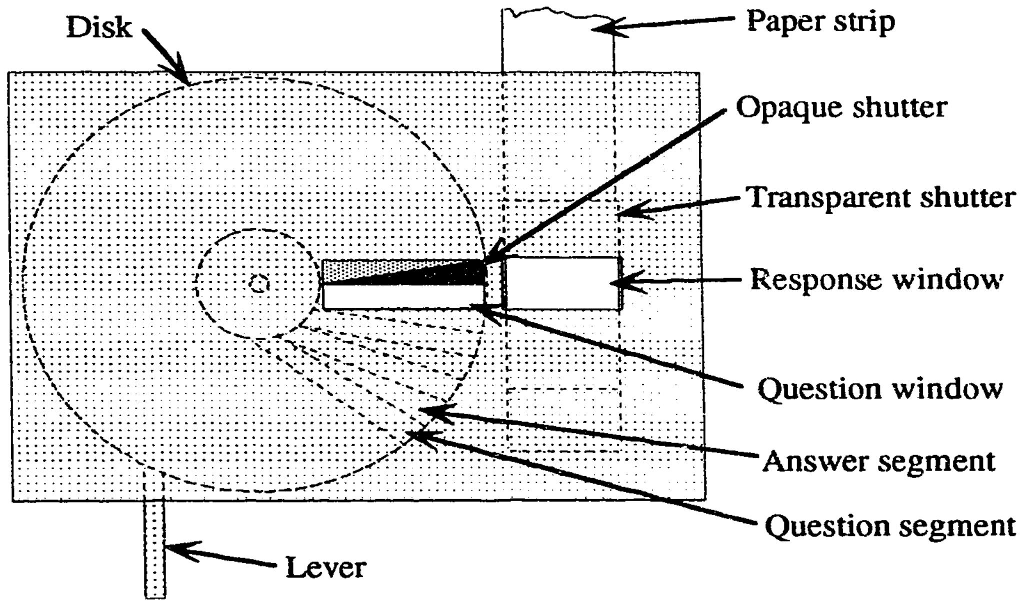


Figure 70. Overhead view of Skinner's disk-type teaching machine

The machine is set initially so that the disk displays the first question. The user writes a response in the space provided in the response window and then moves the lever up as far as it will go. This action causes the transparent shutter to move across the response window. At the same time, the opaque shutter obscuring the answer segment is pulled back, revealing the answer (Skinner, 1958). At this juncture, the user compares his/her response to the answer revealed by the machine. The user is prevented from changing the response by the transparent shutter. If the response matches the answer printed on the disk, then the user moves the lever to the right as far as it will go. This action causes a stylus to punch a hole through the disk as well as the paper strip. The hole signifies that a correct answer has been obtained and it also permits a mechanism to be activated when that question comes around again. If a hole is present in the disk, then the question associated with it is not displayed again. In this manner, the user does not have to repeat questions that were answered correctly on the first try. To reset the two shutters and to advance the disk by one increment so that the next question becomes visible, the user moves the lever to the left and pushes it down as far as it will go. If the written response differs from what is printed on the disk, then the user resets the lever without moving it to the right (Skinner, 1958). The machine is intended to continue presenting questions until they are all answered correctly. Skinner (1958) states, "when the disk revolves without stopping, the assignment is finished" (p. 971). In this respect, Skinner's disk-type teaching machine operates in a similar fashion to Pressey's machine of 1927. Unlike Pressey's testing/teaching machines, however, Skinner's disk-type teaching machines present new information as well as testing recall. Skinner refers to the method that his disk-type teaching machines use to present information in atomistic steps in order to shape behavior, as *programming* or as *programmed instruction*. The purpose of every lesson or program contained on a disk is to achieve a specific goal directly. This type of programming may be referred to as *linear*, since the student reaches the goal through a process of successive approximations and/or vanishing. It is important to consider that the term *programming* is used in a different manner in respect to computers.

Skinner approached IBM with the disk-type teaching machine, hoping that they would develop it along with the slider-type machine. IBM did not express an interest, since they argued that the development of an additional machine might strain available resources (Skinner, 1983). To prove the merits of the disk-type machine, Skinner obtained a grant of $25,000.00 American from the Ford Foundation in 1956, to pay for the production of 10 prototypes for use in Harvard University (Skinner, 1983). A local machinist fabricated them, and they were used in some courses by 1958. Comparisons were made between students who used the disk-type teaching machines and students who did not. Skinner (1983) reports that most students who used the teaching machines obtained higher scores and in less time than students who did not use the teaching machines.

At the same time, Skinner (1983) reports that interest in the disk-type teaching machines was shown by several branches of the American military and by particular corporations, "The armed services and industry were looking for better ways to teach; the educational establishment would have to have them thrust upon it" (p. 131).

While Skinner initially disavowed any similarity between his teaching machines and any antecedent methods or innovations in education, his position changed subsequently, since he compares his machines to the supposed methods of ancient tutors. Skinner (1958) states that the effect of his devices on students, "is surprisingly like that of a private tutor... the machine presents just that material for which the student is ready" (p. 971). Skinner's comparison of his teaching machines to ancient methods might assuage the trepidation of some educators, since Skinner implies that his machines are based on traditional methods of pedagogy. The comparisons are generally invalid, given what has been presented in previous chapters.

Skinner's disk-type teaching machines possess several limitations, and Skinner was aware of some of them. The fixed size of the disk means that a limited number of items may be presented. The items have to be brief, given the small area of each segment. Skinner (1983) reports that the main reason why he used a disk in the machine was because the mechanism could display an item again after it had been answered incorrectly on the first pass. As well, Skinner (1983) questions the appropriateness of repeatedly presenting items answered incorrectly, "I do not know why I thus encouraged 'memorization'. Pressey's machine quite properly allowed for it, but behavior shaped by successive approximation was not learned by trial and error, and in a well-constructed program students made very few errors" (p. 140). It is possible for a student to cheat using Skinner's disk-type teaching machine. If a question is answered incorrectly, there is no mechanism that forces the student to indicate that an incorrect response was made. While Skinner's experiments with undergraduate students at Harvard University were considered successful, it is debatable whether grade-school pupils would operate the machines in the same manner and with the same care as university students. To address some of the limitations noted, Skinner recognized that a different type of machine would have to be designed, and he states that some of the design and engineering aspects were beyond his capabilities (Skinner, 1983). Skinner sought the assistance of a corporation for designing the new teaching machine.

Didak 501 teaching machine

Skinner (1983) reports that he was approached by the Rheem Company in May 1958, who were interested in manufacturing a teaching machine to diversify their market.

Rheem, a metal fabricating company, later purchased a manufacturer of language labs, audio-visual equipment and teaching aids, to assist with their diversification. An agreement was reached between Skinner and Rheem by 1959, to develop an improved version of the disk-type teaching machine as well as a *preverbal* teaching machine, also designed by Skinner. This teaching machine will be described in a subsequent section.

The main improvement made to the disk-type teaching machine was replacing the disk with a mechanism that could transport fan-fold paper past a window. By using fan-fold paper, much larger programs could be developed and it was no longer necessary to write brief items. To keep costs and weight (mass) down, much of the housing was fabricated of plastic. The mechanical components continued to be fabricated of metal. Skinner (1983) notes that he selected the name *Didak* for the machine, deriving the word from the Greek *didaktos*. After much delay, caused in part by operational problems of the prototypes, the Rheem Califone Company marketed a functioning version by 1960, called the *Didak 501*. Figure 71 (author's photograph) shows the external appearance of a Didak 501 teaching machine.

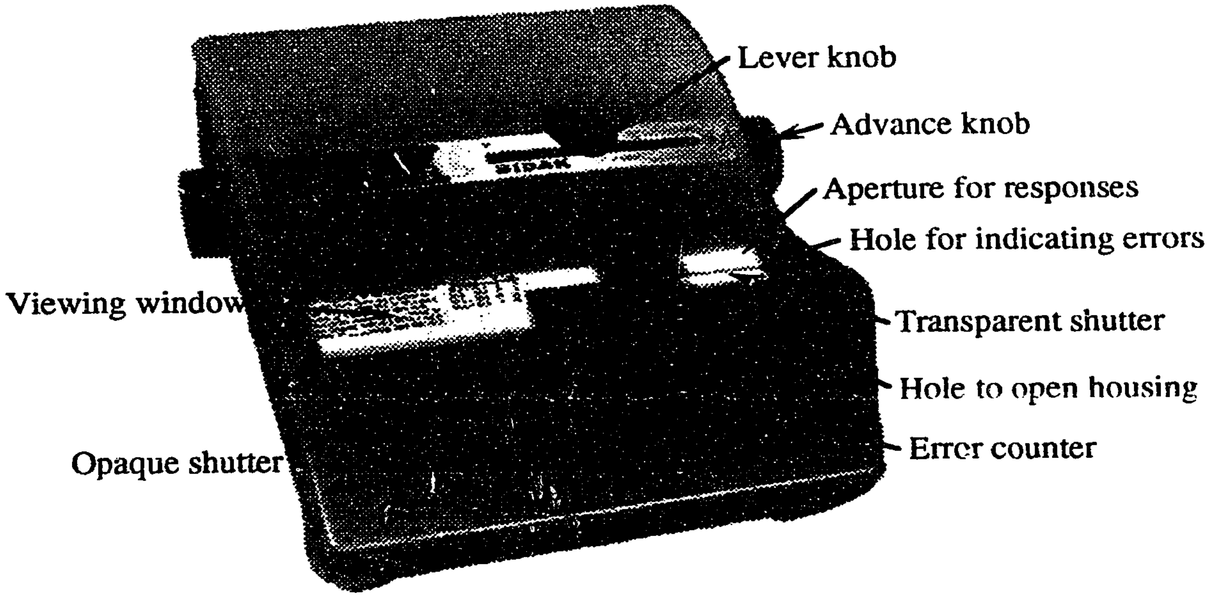


Figure 71. Appearance of a Didak 501 teaching machine

The operation of the Didak 501 is similar to that of the disk-type teaching machines. To advance the program, the user must first move the lever knob to the extreme right. This action causes the opaque shutter to cover the answer area and the transparent shutter to be withdrawn. At the same time, a small opaque shutter is moved which obscures the lower half of the aperture for responses. Movement of the lever to the right also permits the advance knobs to be rotated. It is likely that two knobs are provided to accommodate both left-handed and right-handed individuals. Once a question is aligned in the viewing window, the user may have up to two chances to respond, depending upon how the program is constructed (Foltz, 1961). If the program is designed to provide two opportunities for response, then the student writes his/her first response in the space available in the aperture, above the opaque shutter. Once the response is made, the user moves the lever knob to the left, so that it is located in the middle of its travel. By moving the lever knob to this position, both opaque shutters are moved. The shutter in the aperture for responses is withdrawn completely, while the shutter in the viewing window is moved down half-way, as shown in Figure 71. The withdrawal of the shutter in the viewing window will reveal a prompt or a *hint*, intended to lead the user to the correct answer. The first answer written cannot be altered, since the transparent shutter lies across the upper half of the aperture for responses. The student writes his/her final response in the lower half of the aperture for responses. If the program does not include prompting, then the student moves the lever knob to the centre before writing a response.

The next step is to move the lever fully to the left. This action causes the transparent shutter to block the aperture for responses completely (Skinner, 1961a). At the same time, the opaque shutter in the viewing window is withdrawn completely, revealing the answer. The student compares his/her final response with the printed answer. If they agree, then the student moves the lever knob to the extreme right, and advances the program to the next question. If the constructed response is wrong, then the student pushes a pen or pencil into the hole for indicating errors. This action punches a hole through the paper strip and also pushes a lever inside the machine. The lever raises a pencil that places a mark on the back of the program sheet. At the same time, the movement of the marking lever causes the error counter to advance by one increment. The lever knob is then moved to the extreme right, and the next question is brought into view. Unlike the disk-type machine, the Didak 501 cannot present the same question again.

When the student reaches the end of the program, a pen or a pencil is inserted into the hole to open the housing. This action releases the top of the housing, permitting the student to remove the paper strip. The program sheets may be placed back at the beginning, or a new program may be installed. The student and/or teacher may review the program. The punches in the paper strip, as well as the pencil marks on the back of the program sheets, facilitate review of problem areas.

While the Didak 501 addressed some of the deficiencies found in the disk-type teaching machine, other deficiencies remained. One example is the prevention of cheating. While using opaque and transparent shutters prevents the student from altering a response, the machine has no means of comparing the student's response with the printed answer in the program. There is nothing preventing a student from not indicating an incorrect response. While the student suffers in the long term by this action, it is doubtful whether this consideration occurs to many grade-school students.

Sales of the Didak 501 do not seem to have met Rheem Califone's expectations. Hendershot (1964) reports that the cost of a Didak 501 teaching machine was $157.50 American in 1963. At the same time, Hendershot (1964) notes the availability of at least 40 other teaching machines, some of which operate in a similar manner to the Didak 501, but which were much less expensive. If cost was not a deterrent from purchase, reliability likely was. Leverenz and Townsley (1963) state,

> write-in teaching machines have been torn apart by sixth-graders—by use, not by mischief or malice... There is no reason to expect a technological revolution in education when the machine portion of the man-machine system cannot deliver due to faulty or careless design. (p. 3)

Yet another strike against the Didak 501 was the paucity of prepared programs for it. While some teachers are capable of designing and producing their own programmed materials, others lack the facility, the time, or both. There were also criticisms of Skinnerian behaviorism. Ironically, an outspoken critic of Skinnerian methods and teaching machines was Pressey. Apart from criticizing Skinner's contention that findings with animals could be applied directly to learning in human beings (Pressey, 1963) Pressey (1964b) states that programmed learning as embodied in machines based on Skinnerian behaviorism is usually, "no more efficient than the usual study-reading and almost always more clumsy and more expensive" (p. 413). Pressey (1964b) also prophesied that if teaching machines continued to be manufactured according to this theory of learning, "The present 'boom' may well be followed by a 'bust'" (p. 413). Skinner (1983) tries to dismiss Pressey's criticisms of his teaching machines and theories of learning by stating, "he was missing the point of the experimental analysis of behavior" (p. 259). While this rebuttal of Pressey's criticism may have some basis, it is important to consider that experimental conditions can be obtained rarely in a classroom, so what may be discernible in any number of experiments, may not be replicable in a classroom.

Given these criticisms of the Didak 501 teaching machine, and of Skinnerian-based teaching machines in general, it is not surprising that Rheem Califone discontinued production of the Didak 501 by the end of 1963 (Skinner, 1983). Skinner contends, however, that the only factor contributing to the demise of his machine was mercantile considerations of Rheem Califone. Skinner (1983) states, "Teaching machines had a commercial future, but I was not the man to promote it. I had been altogether too innocent. I should have seen that Rheem was simply 'waiting to see how the ball bounced'" (p. 237). Although Skinner implied that he would no longer try to promote the commercial development of teaching machines, like Pressey, Skinner continued both to development and to promote teaching machines.

Didak 101 and 601 teaching machines

While Rheem Califone was developing prototypes of the Didak 501 teaching machine, Skinner developed another type of teaching machine that could be used by individuals who either lacked verbal development or the ability to read. Skinner (1983) contends that a way of teaching the relationship between speech and writing is to design a teaching machine that associates graphic depictions of objects with particular letters. The machine consists of a housing possessing four viewing windows. The largest one allows the user to see depictions of objects that are printed on fan-fold paper, while the three smaller windows each display a different letter (Finn & Perrin, 1962). Each aperture is covered by a clear plastic cover. Each plastic cover is connected to a microswitch that is closed when the plastic is pressed. A prototype machine was fabricated by Rheem Califone and was called the Didak 101 (Finn & Perrin, 1962). Figure 72 (after photograph in Finn & Perrin, 1962, p. 41) shows general appearance of the Didak 101 preverbal teaching machine.

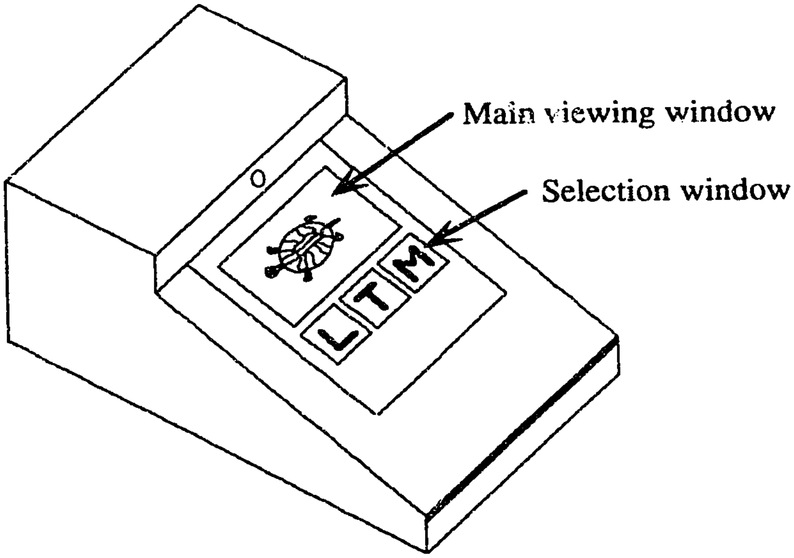


Figure 72. Appearance of the Didak 101 teaching machine

To activate the machine, the user presses the plastic cover of the main viewing window. In most instances, the user is then instructed to press the selection window that displays the first letter of the name of the object depicted. If the correct letter is selected, then the machine advances the fan-fold program until the next drawing and letters are aligned in the windows. An incorrect choice will result in no action taking place. This indicates that another selection must be made (Stolurow, 1961).

Unlike the Didak 501 teaching machine, the model 101 was not put into production by Rheem Califone (Skinner, 1983) although some contemporary accounts describe it as being available (Fry, Bryan & Rigney, 1960; Hendershot, 1964). Skinner (1983) reports that he later tried to have the machine manufactured by another concern, but this effort was unsuccessful too. Rheem Califone designed another teaching machine similar to the Didak 101. Called the Didak 601, the device presents a question in the main viewing window with multiple-choice responses in the smaller windows. There is no indication that the model 601 was put into production. Fry, Bryan and Rigney (1960) claim that this machine was also designed by Skinner, but Skinner does not mention the device in any of his writing.

The design of the Didak 101 and 601 teaching machines seem incongruent with Skinner's theories of learning. It should be recalled that Skinner (1961b) criticizes the theoretical basis of Pressey's machines, because the multiple-choice format presents the user with plausible incorrect material as well as the correct answer. Skinner does not explain clearly why a multiple-choice approach is considered appropriate for pre-verbal learning, but not for other types of learning. In spite of his claim to the contrary (Skinner, 1983) Skinner developed another type of teaching machine which he endeavored to have manufactured commercially.

Skinner's Write and See

Skinner (1983) notes that Pressey gave him a punchboard and several Chemocards in 1955. Although Skinner does not mention Chemocards further, he later claims to have designed, "a system in which acceptable behavior was reinforced by a magic-ink treatment of worksheets" (p. 294). While not multiple-choice answer cards, the principle of operation is remarkably similar to the chemocards.

Named the *Write and See* process, the sheets are printed with various types of invisible inks that become visible when a pen filled with a chemical solution is brought into contact with them. The design of one type of Write and See sheet is similar to the handwriting aid devised by Locke (see Chapter IV). While the user traces an engraved letter with Locke's device, no letters are visible on the Write and See sheets. Instead, the user forms the letter on the sheet within visible guide lines. A letter that is formed correctly reveals ink of one colour, while lines or letters written incorrectly cause ink of a different colour to become visible. In this manner, Skinner (1983) claims that the user not only *emits* responses, but is shaped by the feedback of the different coloured inks.

Like Pressey's Chemocards, the Write and See sheets were not a commercial success. Skinner (1983) does not consider that some of the reasons for the failure of earlier endeavors with invisible-ink instructional devices could impinge upon his innovation in the same ways. Instead, Skinner (1983) blames the failure of his Write and See sheets on teachers, "I soon ran into problems. Teachers were not trained for, and had little time for, many of the things I thought they should do, and standard practices could not be disturbed" (p. 294). Moreover, some of the activities Skinner considered appropriate were allegedly dismissed as *drill* by some teachers (Skinner, 1983). Ignoring the earlier analyses and controversies of the merits of drill by individuals such as Thorndike, Skinner (1983) states, "Drill was out of fashion because it had been taught punitively" (p. 295). Skinner (1983) also admits that there were technical problems with the Write and See system, since he implies that the chemical used to reveal the invisible ink might be toxic, and that the invisible ink might not remain invisible over a long period of time.

Although Skinner's personal ventures into the commercial development of teaching machines were failures, other factors contributed to the widespread development of teaching machines during the late 1950s and through the mid 1960s.

Crowder's theory of intrinsic programming

While the publication of Skinner's articles on teaching machines in 1954 and 1958 did encourage some individuals and companies to develop teaching machines, it should be borne in mind that other work on different types of teaching machines was in progress at the same time. It was mentioned in a previous section on tab items, that Norman Crowder developed a particular variety of tab item that not only indicates an incorrect choice, but which also provides remedial information. Although he became aware of the work of Skinner, Crowder (1959) maintains that the theory of learning underlying his instructional devices is fundamentally different from Skinner's. Crowder (1959) contends that Skinner's teaching machines operate according to a fixed program that follows a direct or a *linear* path to its goal or completion and that this method of operation is an embodiment of Skinner's behavioristic theory of learning. In contrast, Crowder (1959) states that the operating principles of his devices are flexible rather than linear, although Crowder's and Skinner's programs both end at a specified goal. Crowder (1960) states,

> To predictably achieve a desired result, [with a teaching machine] one must either have an infallible process to bring about the result, or one must have a means of determining whether the result has been achieved and of taking appropriate action on the basis of that determination. (p. 287)

While it may be contended that Skinner developed an infallible process by applying his scientific findings with animals to learning in human beings, Crowder (1960) disputes this contention. He maintains that there are a variety of ways that human beings learn, and that a number of personal, environmental and unknown factors determine which way a particular human being will learn at a given time and in a given environment. Describing the operating principle of his devices, Crowder (1959) states, "Each piece of material that the student sees is determined directly by that individual student's immediately precedent behavior in choosing an answer to a multiple-choice question" (p. 109). Depending upon the answer selected, the user will either be presented with the next question as well as an indication that the previous question was answered correctly, or the user will be presented with some quantity of remedial information. In other words, the program deviates or *branches* from a direct linear progression. Programs designed in this way are referred to as either *branching* or as *intrinsic* programs. Crowder (1960) states that the term *intrinsic*, "refers to the fact that the necessary program of alternatives [remedial information] is built into the material itself in such a way that no external programming device is required" (p. 289). Computers are considered by Crowder (1960) to be devices that employ methods of *extrinsic programming*, since input of the user is compared to a separate program that is only placed into the memory of the computer at certain times.

Remedial information may be arranged in several ways, with respect to the main program, in apparatus following Crowder's principles of intrinsic programming. The two main varieties of branches (described in Chapter I) are referred to as *wash ahead* and *wash back* (Crowder, 1960). Branching or intrinsic programs attempt to contend with different levels of previous knowledge among users (Crowder, 1959). Intrinsic programming also considers that a user may not always comprehend the information being presented, hence the inclusion of elements of error analysis. This aspect of Crowder's approach differs from Skinner's methods. Crowder (1963) states, "Linear programs make no explicit provision for errors by the student, since errors are, by linear theory, simply irrelevant to the learning process" (p. 251). While a user might select an incorrect response through a careless press of a key, it is more likely that such responses are made because the user believes that the selection is correct. This belief in turn, suggests that a particular error in logic or comprehension has occurred. It is assumed, furthermore, that remedial information addressing this particular error of logic or comprehension will be appropriate (Crowder, 1959). While this approach may work satisfactorily with set procedures, such as designing a rectifier circuit with specific components, the approach may not be applied as easily to more complex operations, especially those in which there might not be one particular way to achieve the intended goal. Crowder, nevertheless, designed several teaching machines that embody his principles of branching or intrinsic programming.

Crowder's scrambled book

While Skinner designed mechanical devices to function as teaching machines, Crowder's initial efforts entailed the use of simple, non-mechanical apparatus. His design of tab items has been mentioned previously. Crowder does not use the term *teaching machine* to refer to his innovations. Instead, he describes his apparatus as means of achieving *automatic tutoring*. The use of the word tutor is probably intended to equate Crowder's method with some modern impressions of what tutors did in the ancient world (Crowder, 1963). This comparison, in turn, is likely intended to legitimize intrinsic programming and to give the impression that it is descended from venerable methods used in ancient Greece.

To take advantage of the various forms of branching, Crowder designed a special type of book he refers to variously as a *scrambled book* or as a *TutorText* (Crowder, 1960). The initial pages of a typical scrambled book contain information followed by a multiple-choice question. The user is directed to particular pages depending upon which response is selected. Selection of the correct response results in the user turning to the page that contains the next information and question. The user will be directed to other pages in the book when incorrect responses are selected. Different remedial information is presented on such pages. The pages of scrambled books are not arranged in chronological order. In this manner, it is extremely difficult for a user to cheat by flipping ahead to find the answer to a question, since the page corresponding to the correct answer may be located before the page containing the question (Crowder, 1963).

While scrambled books prevent cheating more effectively than printed versions of Skinnerian programs, considerable planning is required for the layout of scrambled books. Although they are simpler and less expensive than most mechanical teaching machines, scrambled books do not appear to have been a widespread commercial success. Greater success was achieved by teaching machines that embody Crowder's intrinsic programming.

Crowder's tutor teaching machines

While scrambled books are capable of functioning according to the principles of intrinsic programming, they are not able to provide a record of the user's progress, nor are they particularly well suited for extremely complex programs that might require several hundred pages (Crowder, 1959; 1963). To address these limitations, Crowder designed an electro-mechanical device that can display information, questions, remedial information, and which can also record both the progress of the user and the time spent with the program (Crowder, 1960).

The apparatus, initially called the *Tutor* (Crowder, 1960) and later known as the *AutoTutor Mark I*, consists of a sheet metal cabinet housing a special indexing 35 mm film projector and a recording device to indicate both the scores of the user and the time spent on the program. The capacity of the projector is 10,000 image frames. A system of electrical relays and vacuum tubes enables the device to display selectively any single frame or sequence of frames. Index marks are placed on the film in the area used commonly for the sound track. Ergonomics are considered to some degree in the AutoTutor Mark I. The cabinet is designed so that the user can sit while using the device. An integral shelf facilitates the correct placement of the user as well as providing a convenient work space. The user is able to enter responses and special requests by means of push-buttons located on the front of the cabinet. Figure 73 depicts the external appearance of the first version of Crowder's AutoTutor.

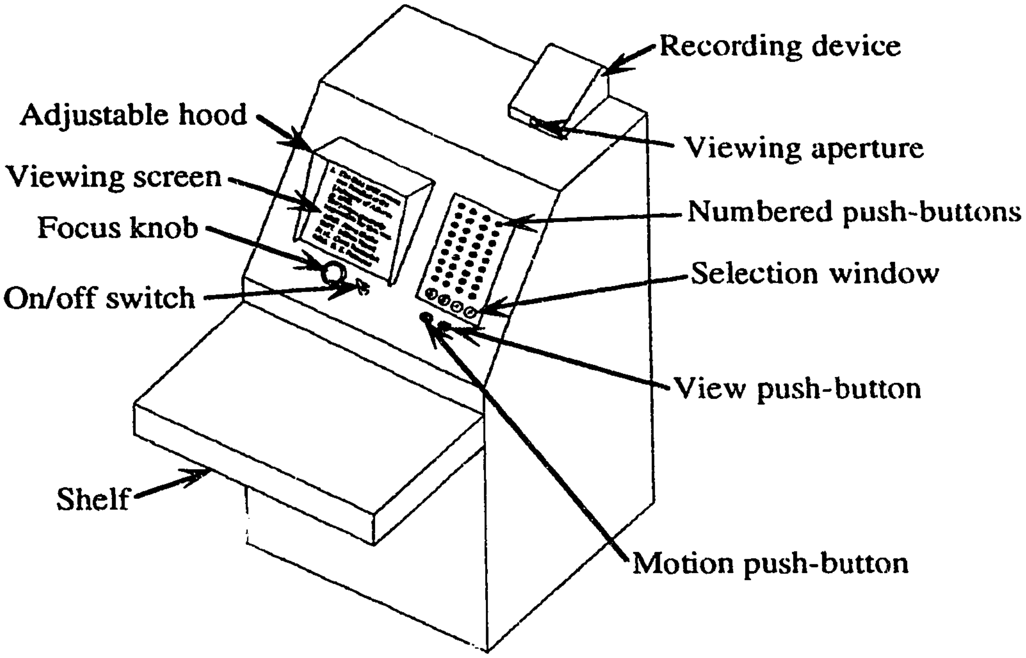


Figure 73. Appearance of an AutoTutor Mark I

The first frame of film is projected once the unit is turned on by means of the on/off switch. Subsequent frames are displayed as the result of numbers entered by the user pressing numbered push-buttons on the machine. Each column of numbered push-buttons corresponds to a selection window located below the column. In this manner, the user may compose a four-digit number which appears in the selection windows. To enter the number, the user presses the push-button labeled *view*. Once that push-button is pressed, the machine will move the film so that the frame corresponding to the four-digit number is projected. The user then proceeds according to the instructions on the new image (Crowder, 1960). In this manner, the autotutor machine functions in a similar manner to scrambled books. Crowder (1959) states, "The automatic microfilm projector in effect turns the pages for the student" (p. 115). Unlike a scrambled book, where the user can flip to the appropriate page quickly, the AutoTutor may take up to 20 seconds to find a particular image (Foltz, 1961). While some other teaching machines appear to do nothing more than act as mechanical page turners (Finn & Perrin, 1962; Hunka, 1962; Gilbert, 1979) Crowder's autotutor can perform other functions as well.

By means of a push-button labeled *motion*, the user may enable certain sequences of frames to be displayed as a motion picture. Colour motion picture film may be used in these sections. Crowder (1960) states that this feature is particularly useful where extreme accuracy of depiction is required, "in such areas as the training of medical technicians" (p. 298). Unlike many other teaching machines, the autotutor is able to record the user's progress through a lesson. An additional feature of the recording device is that it displays, in a viewing aperture, the number of the frame observed previously. Crowder (1960) states that this feature is included, "so that a student who has inadvertently entered a completely wrong number (i.e. a number not included in the choices provided) and thereby gets 'lost' can return to the image he was previously viewing" (p. 298).

Apart from 18 units purchased by the United States military and a lesser number by universities, there is no evidence to show that many machines were sold to schools (Foltz, 1961). A major reason for this is probably the high cost of the unit. Foltz (1961) states that the AutoTutor Mark I cost between $5,000.00-$7,000.00 American, not including the cost of film programs. While particularly wealthy schools or school districts that received a special grant might afford one unit, most schools and school districts did not possess sufficient funds to purchase any examples. Another aspect of the Mark I that can be considered detrimental, is the difficulty of film replacement. The side of the cabinet must be removed to reach the film reels. Removal of either side panel exposes electrical apparatus inside the machine. Although the precaution of unplugging the machine can be taken, it is still possible to receive an electric shock or burn from some of the exposed components. Exposed wires and vacuum tubes are also susceptible to physical damage. A simpler and less expensive machine was designed subsequently by Crowder.

Called the AutoTutor Mark II, its appearance is markedly different from the Mark I. Instead of being housed in a large cabinet, the AutoTutor II is contained in a plastic and metal housing designed to be placed on top of a table, desk or other flat work surface. As with the Mark I, programs are contained on 35 mm film. Smaller film reels are required to permit them to fit within the housing. Programs cannot exceed 5,000 frames, therefore (Fry, 1963). The design of the Mark II facilitates film and projector bulb replacement. The projection apparatus is located beneath a hinged lid that is easily accessible. While the possible hazard of electric shock and unintentional damage to the machine is reduced in the Mark II, the proximity of the projection lamp to the film reels presents a possible burn hazard when a film is changed immediately following the use of the machine for a protracted period.

There are only 10 push-buttons on the front of the machine. Nine are for selecting responses, while the tenth enables the user to return to the previous frame viewed. This model has no provision for displaying motion pictures, but it does have the ability to be connected to a synchronized tape player (Foltz, 1961). Figure 74 depicts the general appearance of the AutoTutor Mark II.

In spite of its diminutive size as compared to the Mark I, the AutoTutor Mark II possesses a mass of 46 pounds (21 kg) (Gille, 1965). In 1961, the Mark II sold for $1,200.00 American and could also be purchased through a rental/leasing agreement (Foltz, 1961). While considerably less expensive than the Mark I, the Mark II was still expensive relative to other teaching machines. There is evidence to show that some schools purchased several examples of the Mark II (*Educational Technology*, 1966, cover; Bridwell, 1967). The availability of suitable programs appears to have been a perennial problem (Finn & Perrin, 1962). An advertisement for the AutoTutor Mark II, that appeared in 1965, states that 60 programs are available and that another 30 will be available by the end of the year. The same advertisement also states in bold type, "Have YOU written a program? Let us review it; we're always looking for additions to our growing library of standard programs" (U. S. Industries, 1965, p. 411).

The AutoTutor Mark II remained in production until the late 1960s, when it was replaced by the Mark III. This model is similar in appearance to the Mark II, except that the lettered push-buttons are arranged in a circular fashion in the Mark III. It is not known why this change was made. The Mark III was marketed by Welch Scientific Company, the same firm that had marketed Pressey's testing/teaching machines over 35 years previously. The successor firm, Sargent-Welch, sold the AutoTutor to another company, but production was discontinued by the late 1970s (correspondence with Robert Bieser, Vice President, Sargent-Welch Scientific Company, May 10, 1989).

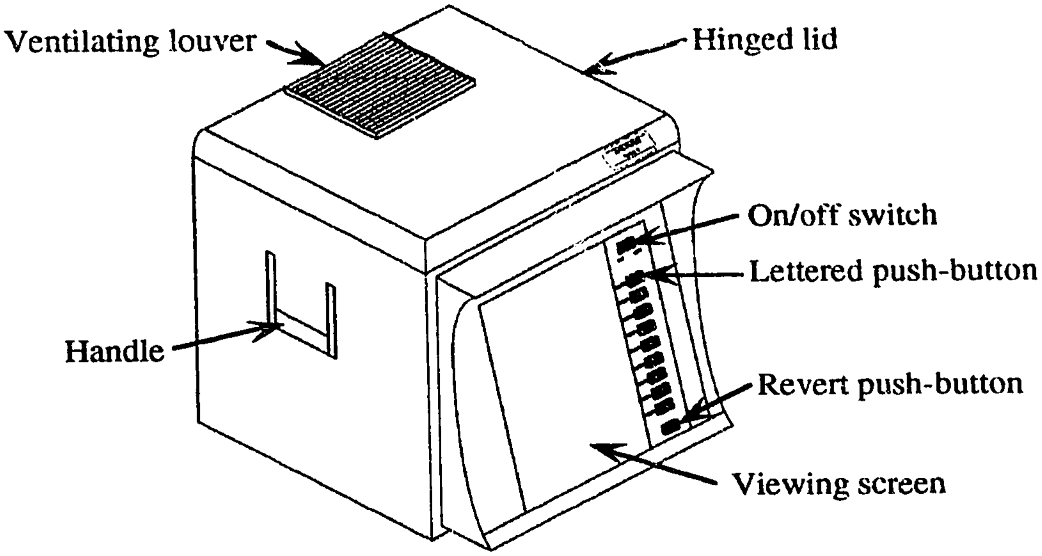


Figure 74. Appearance of an Autotutor Mark II

From what has been described and discussed in the previous sections, it is apparent that by the beginning of the 1960s, there was considerable interest both in the manufacture of teaching machines and their deployment. The next section describes some of the developments and factors contributing to this so-called *teaching machine movement* (Wohlwill, 1962).

Teaching machine movement

Rise of popularity

Although Skinner published the existence of his teaching machines as early as 1954, widespread interest in and promotion of teaching machines did not occur until the late 1950s. One of the most important factors contributing to increased interest in teaching machines was the launch of Sputnik I by the Soviet Union in 1957, and subsequent concern in the United States that public education in that country was inferior and inefficient, thus allowing the Soviets to outstrip American efforts in science and technology (Edelman, 1958; Skinner, 1986; Reiser, 1987). A consequence of this concern, was the introduction in the United States of the National Defense Education Act in 1958. Funding under this act existed for a period of 10 years and over 40 million dollars American was allotted to projects concerned with the development and use of *media* (instructional devices) in education (Reiser, 1987).

Another factor leading to the proliferation of teaching machines was the interest in them shown by the United States military. It has been mentioned in previous sections that the military was responsible for much research and development of instructional devices. The military was also the largest customer of Crowder's AutoTutor Mark I. Cohen (1961) states that the advent of the National Defense Education Act coupled with interest in teaching machines by the military, resulted in an increase of teaching machine manufacture.

It was mentioned near the outset of this chapter, that the notion that schools and teaching will become mechanized since most other endeavors have become mechanized, is another factor that contributed to the interest in and the deployment of teaching machines. There is evidence to show that this factor was enhanced and exaggerated by some individuals and corporations who desired to increase their sales of teaching machines and other instructional devices. For example, an advertisement for the Videosonic line of teaching machines, manufactured by Hughes Aircraft Company, claims that the use of their teaching machines, "1) Cuts training time by 50% and more 2) Gives 70% greater retention 3) Increases comprehension average of 50%" (Hughes Aircraft Company, 1964, p. 631). All of the aforementioned claims are meaningless when applied generally to a variety of different teaching and training situations. A different approach was taken by the Koncept-O-Graph Company (1961; 1962). Their advertisements imply that by not using their teaching machines, a classroom is not being run efficiently, thus wasting both time and money. While few studies were undertaken initially to ascertain the effectiveness of teaching machines, some individuals, nevertheless, persevered in promoting teaching machines in an enthusiastic fashion (Skinner, 1954, 1958; Mager, 1959).

Wohlwill (1962) comments that since 1958, "the teaching machine movement has been growing in a band-wagon fashion" (p. 139). While the claims of some individuals and corporations suggest that this was the case, it may be asked if there is any other evidence to support this view. A tabulation of articles concerned with teaching machines, listed by number per year, might provide a rudimentary reflection of academic interest in teaching machines. The idea of compiling such a tabulation is not new. Fry, Bryan and Rigney (1960) compiled such data, but their tabulation is deficient in two ways. First, it does not contain any information beyond 1959, so longitudinal trends are not discernible. Second, the authors also include a number of unpublished works, such as theses and private studies. While such works are academic in nature, they are usually not widely available, so their inclusion may skew the results by showing a higher level of general interest. Fry, Bryan and Rigney (1960) provide no means of distinguishing between published material and unpublished material.

To provide a better indication of academic interest in teaching machines generally, a graph has been prepared that plots the data gathered by Fry, Bryan and Rigney (1960) as well as data gathered from listings of published material in the *Education Index*. The graph is intended to be a rough indication only, since there are publications not reviewed by *Education Index* and since headings as well as criteria for particular headings change over time. It is for the last reason that the graph also plots the numbers of publications listed in the *Education Index* under the heading *programmed teaching*. Wherever possible, duplicate entries in two or more headings were recognized and eliminated. Figure 75 (compiled from information in Fry, Bryan and Rigney, 1960; *Education Index*) depicts the year and number of references concerned with teaching machines and programmed instruction.

Considering the general trend of the plots, it appears that academic interest in teaching machines as well as programmed instruction increased until the early 1960s and then began to wane towards the end of that decade. The decline in numbers of publications likely reflects the conclusion of funding provided by the National Defense Education Act. Interest in teaching machines appears to rise again, but diminishes by the mid 1970s. This rise appears to be the result of the *Education Index* including articles about computer assisted instruction under the heading *teaching machines*. The final rise in publications, occurring between the late 1970s and the early 1980s, reflects the inclusion of some publications concerned with microcomputers. It is apparent from the graph that current interest in teaching machines appears to be at a low level. The same may be said of programmed instruction. This category has taken longer to reach the low level of the teaching machines category. One explanation for this phenomenon, is that the category of *programmed instruction* includes most publications concerned with the subject as well as publications addressing the philosophies and the learning theories of programmed instruction. The category also includes some publications about computer assisted instruction and others about the use of microcomputers.

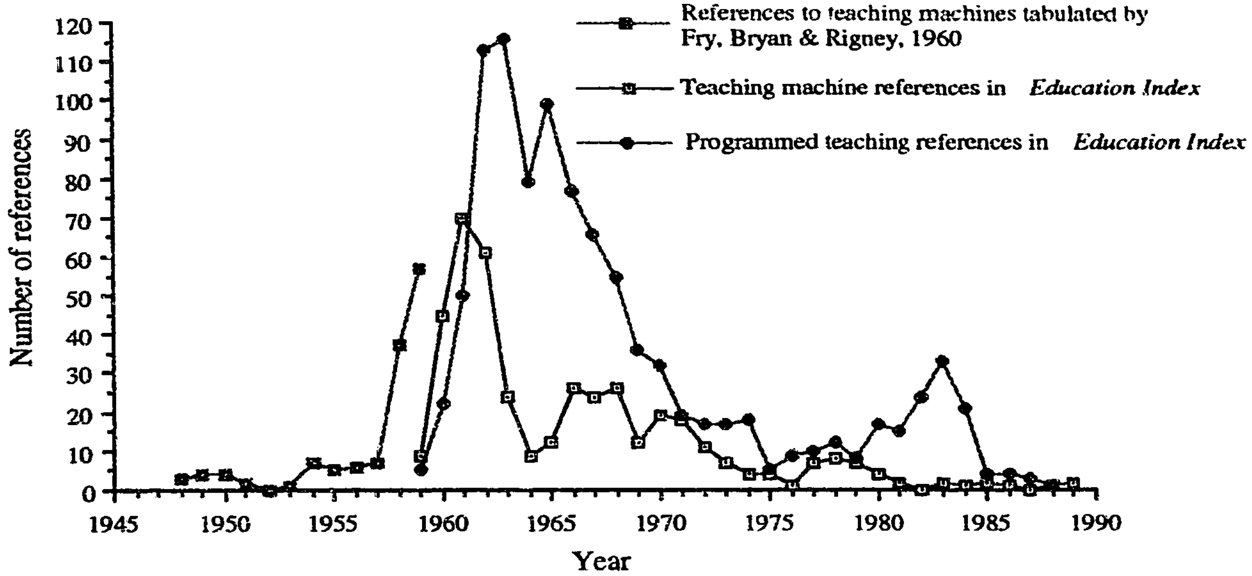


Figure 75. Graph of teaching machines and programmed instruction references per year

While it appears that there was academic interest in the *teaching machine movement*, it may be asked whether this interest extended to the commercial production and promotion of teaching machines.

Commercial production

While Pressey and later Skinner both had difficulty in getting their teaching machines manufactured and marketed, there is evidence to show that many different varieties of teaching machines were being marketed between the late 1950s and the end of the 1970s. Appendix A is a listing of teaching machines manufactured in North America and Western Europe that were advertised or listed in catalogues as being available commercially. Teaching machines described in the literature either as experimental or as being manufactured solely for private or restricted use, such as the subject matter trainer, are not included in the list. While steps have been taken to ensure the completeness of the listing, it is possible that some models are not included.

Each entry notes the names of the manufacturers, the model name, a brief description of the device, the predominant construction material, the year the apparatus was introduced to the market, indications as to whether or not the apparatus is mechanical or electrical, the design of program used (see Chapter I) and the cost of one example in a particular year.

Some information in the list was obtained from extant companies or their successors. In the search for this data, 102 manufacturers of teaching machines were identified and attempts were made to ascertain both their corporate status and their current address. Sixty-eight companies either could not be traced or their current address could not be located. Of the 34 companies approached, 18 or 53% responded to requests for information. No response was received from the remaining 16 companies. Two methods of gathering data were used. Initial requests were made by letter. While this approach yielded some returns, it was believed that a different approach could be used in follow-up with the companies that did not respond initially. An eight-item questionnaire, designed companies that did not respond to the initial letter. The information gathered also established whether particular machines were ever put into production and actually marketed.

The listing in Appendix A is subdivided into categories according to the apparent theoretical basis of each teaching machine. These subdivisions are also intended to highlight the various strategies used by particular companies in marketing their devices. It has been noted in Chapter V that by the 1950s, most educators accepted the use of teaching aids. It is apparent from descriptive literature and advertisements that several companies thought that potential sales of their teaching machines might be improved by combining an unknown and possibly unreliable innovation, teaching machines, with established and widely accepted teaching aids. In some instances it was contended that to gain the maximum effectiveness of teaching machines, they must comprise a part of an integrated system of instructional devices that may include teaching aids, television, films, and instructional laboratories following the principles of language laboratories (Schure, 1963). Many of these instructional laboratories, sometimes referred to as *feedback classrooms* (Holling, 1967) consist of teaching machines with electrical connections to lights, counters or similar indicators located on a feedback panel placed on or near the instructor's desk. The purpose of the feedback panel is to enable the instructor to monitor the progress of each student so as to optimize the provision of assistance. The *Mata System* manufactured by the Canadian firm Alda Instruments, as well as the *Teletest* and the *Quizzo* devices, are examples of such integrated instructional systems (see Appendix A). The high cost of such systems as compared with the cost of a teacher is a likely reason why so few systems were marketed.

Another reason that teaching aids were combined with teaching machines was to make them both more versatile and better equipped to compete with other instructional devices such as computers. For example, Dorsett (1971) whose company continues to produce one model of a teaching machine, contends that his *audio-visual teaching machines* are more versatile than computer-assisted instruction, "These new machines not only would show the student a visual presentation, but also they would minimize the reading burden by talking to the student, or playing sound effects" (pp. ix-x). Dorsett (1971) contends further that teaching machines incorporating audio-visual teaching aids, "provide two of the key features of CAI, individualized instruction and self-pacing, at a fraction of the cost... Why don't educators and training directors eagerly accept a low-cost learning system which appears to have obvious advantages for greatly increasing the learning rates of most students?" (pp. x, 97). Attempting to answer his own question, Dorsett (1971) cites reluctance to change, the potential *dehumanizing* effect of teaching machines, "women's sheer fear of mechanical devices", and the lack of requiring schools to be *cost-effective*, as reasons why audio-visual teaching machines are not accepted widely (pp. 97-100).

Unlike some other manufacturers, Dorsett (1971) considers the rôle of theories of learning, but to a limited extent. It is clear both from his descriptions and from the machines themselves that they are based on the principles of Skinnerian behaviorism. While Dorsett accepts readily the claims of Skinner and others, that teaching machines which embody the principles of Skinnerian behaviorism decrease the time required for students to learn a given task, Dorsett does not appear to accept the reasons why many educators had moved away from using such behavioristic methods to other methods of instruction that Dorsett (1971) terms *cognitive*.

In spite of Dorsett's claims that audio-visual teaching machines are appropriate for schools because of versatility, low cost and higher cost-effectiveness, and by implication, a better method of pedagogy and theoretical basis, it seems that most contemporary sales of teaching machines are made to corporations as well as to private individuals in conjunction with the sale of encyclopedias. Both the E.L.F. and the Min/Max Model III teaching machines are marketed primarily with encyclopedias (Correspondence with Macmillan Educational Company, March 21, 1989; Lexicon Publications, February 12, 1988). At least one machine, the System 80, continues to be purchased by schools, although the market is limited (Correspondence with Educational Technology Corporation, December 14, 1988).

While earlier sections of this chapter describe some of the teaching machines listed in Appendix A, most teaching machines listed are not described in detail. Given that the intention of this work not to be a catalogue of devices, and given the descriptions already provided in this chapter, it likely that most readers will be able to comprehend the general function and appearance of most of the teaching machines listed in Appendix A. The accounts of Finn and Perrin (1962) and Gille (1965) both contain photographs of several models of teaching machines.

Particular model names of teaching machines listed in Appendix A that appear in bold type, indicate that the teaching machine was in production at the time of the survey. Other model names that appear in italicized bold type signify that the particular model was advertised, but was never placed in production. Figure 76 (compiled from data in Appendix A) is a pie chart showing the percentages of the teaching machines listed in Appendix A that are in production as of 1989, never placed in production and those no longer in production.

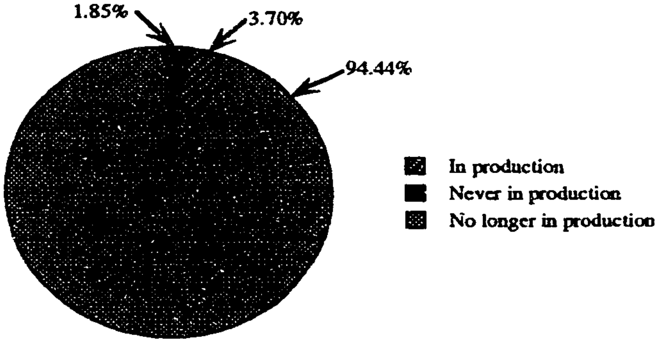


Figure 76. Pie chart showing percentages of teaching machines: in production, out of production, never in production

It is clear from Figure 76, that most electro-mechanical teaching machines are no longer in production, regardless of the theoretical basis or the type of programming used. Although Appendix A notes comparatively few teaching machines that were advertised and never placed on the market, it is reasonable to ask why these models were never marketed. An earlier section of this chapter notes that the Didak 101 model teaching machine was advertised, but was not placed in production, and that Skinner's explanation for this is his contention that Rheem Califone did not think that the potential market would provide a suitable return. Apprehension about marketability seems to be a factor limiting the production of other teaching machines.

During the late 1950s, when the teaching machine movement was getting underway, it appeared as if both funding and the potential market for teaching machines were about to expand (Edelman, 1958). Foltz (1961) notes that some trade publications estimated that the annual market for teaching machines would be worth 100 million dollars American. Others such as Fine (1962) predicted that by the late 1960s, there would be an acute shortage of teachers in the United States and that some extraordinary means of instruction would be necessary to supplement existing teacher training methods. Perceiving a lucrative and developing market, it seems that several manufacturers, including Rheem Califone, hastened the development of teaching machines to capitalize on the market before it became saturated. Foltz (1961) states, "The commercial rush to get into the field of 'teaching machines' has led many firms to produce 'hardware' without any thought of programing. Without programs, their devices are costly and useless" (p. 12).

Cohen (1961) also shares Foltz' observation, and he cautions educators not to buy any instructional device unless appropriate and suitable programs are available with it. Foltz (1961) predicted that the problem of a surplus variety of machines with few programs would solve itself, "The present tendency to unplanned proliferation by industry will soon dry up as stockholders demand that such research and development be put on a more sturdy, paying basis" (p. 53). Not only did some companies abandon the manufacture of teaching machines altogether, but some companies aborted plans to enter the market. Both Williams International, formerly Williams Research Company responsible for the *Science Desk* teaching machine, and the Farrall Instrument Company, responsible for the *Touch-tutor Mark 2M* teaching machine, indicate that their respective machines were not marketed because of apprehensions about marketability and sales potential (correspondence with Williams International, March 7, 1988; Farrall Instrument Company, September 23, 1988).

It has been shown that there was widespread interest in teaching machines in academic circles and that many concerns showed interest in manufacturing teaching machines. It may be asked to what extent were teaching machines used by schools and other institutes of education?

Deployment and use of teaching machines: United States

Educational institutions

Although responses to requests for information were received from 53% of the companies approached who manufactured teaching machines, some firms such as the Macmillan Educational Corporation and Lexicon Publications would not reveal the number of units sold (Correspondence with: Macmillan Educational Company, March 21, 1989; Lexicon Publications, February 12, 1988). Other corporations, such as the Sargent-Welch Scientific Company, no longer retained records of the number of teaching machines manufactured and sold. In consequence of these conditions, information about the number of teaching machines sold was obtained from only five companies: Didactics Corporation, 4,000 units of model Didactor DTR 300; Dorsett Industries, 250 units of model M 20, 2,000 units of model M86 and 3,000 units of model M99; Field Enterprises/World Book, over 5,000 units of the Cyclo Teacher; Ken Cook Company, 6,260 units of model SR100, and Educational Technology Company, over 70,000 units of the System 80. Respondents indicate that most of their production was sold to grade schools and to colleges.

A few of the teaching machine models remaining in production are still purchased by schools. For example, the Educational Technology Company reports that they sell approximately 500 units a year of the System 80 to schools. Some of the sales entail large purchases by a single school or school district. In 1988, it is reported that Little Rock, Arkansas schools purchased 144 units (Correspondence with C. M. Hayes, Vice President, Educational Technology Corporation, December 14, 1988). It is also noted that while the continued success of this teaching machine appears anomalous to some individuals who contend that the technology is obsolete, the cost of acquiring units is frequently underwritten by the Federal Government of the United States (Correspondence with C. M. Hayes, Vice President, Educational Technology Corporation, December 14, 1988).

Few studies appear to have been published that assess teaching machine usage on a national level. One study that does include such information, conducted by the United States Federal Office of Education, summarizes data gathered nationally between 1961 and 1963. Hanson and Komoski (1965) report that in each year of the study, questionnaires were sent to each school system in the United States, over 14,000, inquiring about their use of programmed instruction. Hanson and Komoski (1965) note that most responses indicate that no variety of programmed instruction was being used, and that the percentage of school systems using some type of programmed instruction ranged between 11% and 36%. It is reported further that of the respondents who indicated using programmed instruction during the school year 1961-62, 73% did not use teaching machines. For the year 1962-63, this number rose to 79%, indicating that fewer schools were using teaching machines. Arnett, Trout and Clarke (1962) provide additional evidence to show that some schools using teaching machines were abandoning them in favour of scrambled books and other non-mechanical methods of programmed instruction. Fine (1962), Bridwell (1967) and Lee (1970) describe the apparent successful and continuing use of teaching machines in specific schools or in localized areas. Most of these reports describe specific teaching machines, but the total numbers used are not indicated. For example, Platt, Cifelli and Knaus (1966) describe teaching machines manufactured by the Mast Development Company, but they provide only a vague indication as to how extensively they are used, "The Mast Teaching Machine is used as a teaching aid in a number of school settings throughout the country" (p. V-0).

An indeterminate number of schools used teaching machines with students possessing special needs. Stolurow (1963) notes 14 extensive projects, funded largely by the United States Federal Government, that employ methods of programmed instruction with students possessing mental disabilities. It is not discernible how many teaching machines were used in these projects, or how long the use of programmed instruction continued when government funding ceased. Stepp (1966) describes the use of different visual teaching machines to help instruct lip reading to deaf students. While some devices manufactured commercially were used, other instructional devices were made under the auspices of the institution providing instruction.

Platt (1965) notes the use of Devereux *model 50, Learn Ease* and Mast Development Company's model *1700* teaching machines with mentally retarded and emotionally ill adolescents. The three-year experimental project begun in 1963 by the Devereux Foundation of Devon, Pennsylvania, was conducted in the Devereux schools. Platt (1965) states that the use of teaching machines was received favorably in this project, primarily because individual students could proceed at their own speed. A later report, Platt, Cifelli and Knaus (1966) indicates that considerable planning took place before any teaching machines were used. In this instance, teaching machines were used to address a *perceived need* only after the theories behind teaching machines were evaluated as well as the design of the machines themselves. Not satisfied with most teaching machines available commercially, Platt, Cifelli and Knaus (1966) report that the Devereux Foundation designed the Devereux Model 50 teaching machine and that it, "was planned particularly for use with the slow learner" (p. III-0). Besides using this particular teaching machine with slow learners, assembly of the units was undertaken by their students in sheltered workshops after they first learned assembly procedures from teaching machines. Workbooks for use with the teaching machines were also assembled in this manner (Platt, Cifelli & Knaus, 1966). The manufacture of the Devereux Model 50 teaching machine represents one of the few examples, or perhaps the only incidence, of an educational institution both designing and assembling a teaching machine for commercial sale. Although Platt, Cifelli and Knaus (1966) report that the experiment was a success and that manufacture of the Devereux Model 50 teaching machine would continue as long as they were in demand, it is not known how many examples were manufactured or to whom they were sold.

Teaching machines were used for instructional purposes within some hospitals and medical faculties. Bridgman (1964), Polony (1965), Stahl and Hennes (1973), Stevens, et al. (1973) each describe the use of teaching machines in specific areas of medical education. A number of *Didactor* teaching machines were used in at least one hospital to instruct particular patients about aspects of specific illnesses and treatments (Information from Didactics Corporation, June 8, 1989). From the literature available, it seems that teaching machines were used less in medical education than in grade schools in the United States.

While evidence has been cited to show that teaching machines have been and continue to be used in some American educational institutions, it has also been shown that the zenith of teaching machine use in most American schools was reached in the early 1960s and has been in decline since.

Military

From what has been noted in previous sections of this chapter, there is little doubt that the United States military has had the most sustained interest in teaching machines than any other group since the Second World War, a view shared by Margulies and Eigen (1962). While some devices such as Pressey's punchboard were designed outside of the military, other devices such as the tab item and erasable overlay devices, have been designed within the military itself and were later made available commercially. For some teaching machines, such as the AutoTutor Mark I, the military has been the biggest customer. Eckstrand, et al. (1961) state, "Training has always been one of the factors of vital importance to efficient military operations and in recent years has definitely become big business within the military" (p. 1). The authors contend that teaching machines not only provide a possible solution to the high cost of training military personnel, but that teaching machines also establish rigid and consistent standards of training by the way they address individual differences in rates of learning. There are many articles that describe experimental and pilot usage of teaching machines in various branches of the military. Examples include Gagné (1954), Briggs (1958), Crowder (1959), Bishop and Regan (1962) and Hosmer and Nolan (1962). Individuals both within and without the military have also conducted experiments comparing the effectiveness of teaching machines with traditional methods of training and instruction (see Lumsdaine & Glaser, 1960; Margulies & Eigen, 1962). While the findings from most of these studies suggest that learning is more efficient by using teaching machines, the military was reluctant to use teaching machines on a large scale, mainly because the devices had no proven long-term success (Eckstrand, et al., 1961). Bishop and Regan (1962) note that while studies have answered some questions about whether or not the use of teaching machines results in more efficient learning, other questions such as whether or not teaching machines produce a *novelty effect* have not been addressed satisfactorily. Instead of implementing teaching machines on a large scale, the military has retained traditional methods until it can be established that the long-term effects of using teaching machines are as favourable as they have been in short-term studies. The prevalent attitude in the military towards the use of teaching machines is summed up by Bishop and Regan (1962) who state, "The trend in the armed forces, then, is one of cautious optimism. The research, development and application resulting from this trend should benefit both the armed forces and education in general" (p. 68). Subsequent widespread use of teaching machines in the military does not appear to have taken place, however.

Industrial training

Although many individuals including Pressey, LaZerte and Skinner designed their teaching machines primarily for use in schools, there is evidence to show that teaching machines are also used by particular industries to train selected personnel. Lysaught (1962) states that interest shown in teaching machines by educators, the military, the news media, and the claims that teaching machines represent, "the greatest breakthrough in education since the printing of the first text book" (p. 23) has caused some businesses to become interested in new methods of training. Moreover, Lysaught (1962) states, "these claims [about teaching machines] are made seriously – by men of proven ability – they dare not be ignored" (p. 23).

Deutsch (1962) indicates that the use of teaching machines by industries increased markedly between the late 1950s and the early 1960s, stating that in 1961, over 63 "major industrial corporations" were using teaching machines for some aspect of personnel training, as opposed to only three companies in 1959 (p. 208). Although the data compiled by Deutsch (1962) indicates a trend of increasing use of teaching machines by industries, information available currently suggests that the trend did not continue, but that some industrial concerns continue to use teaching machines in spite of their general unpopularity.

Most companies that produced teaching machines, and which responded to letters and questionnaires, state that the majority of their sales were to educational institutions. Some companies indicate that teaching machines continue to be purchased by industries. It appears that an industrial market for teaching machines continues to exist. For example, the Didactics Corporation indicates that during the mid 1960s, several Didactor teaching machines were used successfully to train some personnel of Republic Steel. The Didactics Corporation cites four main reasons why industries should consider using teaching machines for training: 1) they save money, since they are cheaper than hiring a trainer; 2) the use of teaching machines produces favourable results; 3) training may be performed at any time, so complex schedules need not be disrupted; 4) employee may take the unit home and train in the evening, and not use company time (Correspondence with Didactics Corporation, June 8, 1989). The use of teaching machines within industry appears to be somewhat successful, since Didactics reports that Didactor teaching machines were used by the ITT company between 1984-86 to teach engineers and computer programmers a computer language and operating procedures for new telecommunications equipment (Correspondence with Mr. J. Hannah, Didactics Corporation, June 8, 1989). Other companies that manufacture teaching machines also report that some industries continue to purchase and use their teaching machines.

Ken Cook Educational Systems report that their teaching machines continue to be purchased both by industries with discrete training programs and by those using on-the-job training techniques (Correspondence with Ken Cook Educational Systems, February 18, 1988). Dorsett Industries state that their model M 99S teaching machines are being used by several private companies as well as by particular departments of the United States Federal Government, including U. S. Customs, the Postal Service, Meat and Poultry Inspection and the Bureau of Indian Affairs (Correspondence with Dorsett Industries, September 19, 1988).

Several large companies either use or have used teaching machines as a part of personnel training. Examples include Westinghouse, Bell Telephone, General Precision and Esso (Fine, 1962; Gille, 1965). At least one large corporation has used teaching machines because other training methods were considered to be too expensive. Lysaught (1962) reports that the Eastman Kodak Company, which employed approximately 74,000 persons world-wide in 1961, decided to use teaching machines because, "it was already obvious that paper costs and handling [for paper-based methods of programmed instruction] would be significant" (p. 30). Several teaching machines available commercially were evaluated. Lysaught (1962) notes that one limitation of the teaching machines designed by Skinner is that the question and answer windows are too small to accommodate items that include or require illustrative material. Another concern was the reliability of supply and a stable cost for whatever machine might be selected. Finding no teaching machine that met all of their requirements, Eastman Kodak decided to design their own (Lysaught, 1962).

Kodak developed the Mentor I model teaching machine by 1960. Although it was also marketed commercially, it was designed primarily for use within Eastman Kodak (Lysaught, 1962). Sales of the Mentor I outside Eastman Kodak were apparently not satisfactory, since a new version, the Mentor II, was released in 1962. The explanation given for the poor sales of the Mentor I, is that it had no provision to accept a constructed response by the user. Lysaught (1962) states, "we recognized that for the present and immediate future, most programs under construction are patterned after the Skinner [constructed response] model. For this reason, we constructed a second model of the device which was considerably smaller and less expensive to build" (p. 33). The Mentor II does not seem to have met with sustained success. Eastman Kodak later sold production of the Mentor teaching machine to another company and Kodak itself discontinued using teaching machines (Correspondence with Eastman Kodak Company, March 18, 1988).

Home market

Perhaps the most enigmatic areas concerning teaching machines are how they are marketed to society in general and how teaching machines are perceived by parents and individuals at large. Several teaching machines including the Koncept-O-Graph, the E.L.F. and the Min/Max III, either were or still are marketed to the general public in conjunction with sales of encyclopedias. Pressey (1967) notes that teaching machines sold door-to-door or otherwise sold to the general public are presented by sales people who frequently embellish their marketing by presenting extravagant claims about the effectiveness of teaching machines. Soles (1963) also concurs with this observation. One type of claim implies that the use of a particular teaching machine will impart a knowledge of facts to the user that will be superior to the knowledge of others. Another type of claim attempts to focus the attention of parents on the seemingly competitive nature of school. By having their children use the teaching machine being sold, parents can ensure that their children will be better prepared for school than other children, thus implying that higher-than-average grades will be achieved. A chart used by sales people for marketing the Min/Max III teaching machine contains a testimonial from a parent that states, "Our daughter is now in first grade and in the top reading group" (Information from Lexicon Publications, Inc., February 12, 1988). While use of the Min/Max III teaching machine may have resulted in the position of the student in the top reading group, there may be other factors responsible. Another testimonial from the same sales chart claims, "My daughter is doing excellent [sic] in school with the help of your programs" (Information from Lexicon Publications, Inc., February 12, 1988). This parent also concludes that the use of the Min/Max III teaching machine is responsible for the daughter's high performance.

Skinner (1983) also notes the phenomenon of marketers using extravagant claims to sell their teaching machines, and he adds that some of the claims involve the unauthorized use of his name as an endorsement. Marketing of teaching machines can also entail the distribution of them to individuals who might not have a need or use for them. Pressey (1964a) states that he received a teaching machine, "made of pasteboard and about the size of a 500-page volume" as a bonus for spending a given amount of money in a particular store (pp. 361-362). While giving away teaching machines might induce some individuals to buy more of them, it is possible for the strategy to backfire with some individuals who consider them to be expensive and useless gadgets.

The concerted selling of teaching machines to the home market may also have been a vehicle by which some marketers attempted to induce parents to inquire of their respective school boards why teaching machines were not being used extensively in schools. While it cannot be established conclusively that this strategy was employed, there is evidence to show that public pressure influenced some officials responsible for education. For example, Fine (1962) quotes the Superintendent of Public Instruction for California as stating, "Parents are buying teaching machines at an impressive clip. Schools must not be the last to recognize their value" (p. 24). Unless Fine (1962) misquoted the Superintendent, the impression given is that schools should adopt pedagogical methods popular with parents, not necessarily those methods that are considered to be effective professionally.

While the use of teaching machines in most American schools has declined since the 1960s, there is evidence to show that home sales of teaching machines continues to be a viable market.

Deployment and use of teaching machines: Canada

Educational Institutions

Like the United States, initial interest was shown in teaching machines as experimental devices by universities and by school systems. It appears that Canadian interest in teaching machines began in the early 1960s rather than the late 1950s, and there is evidence to show that early findings with teaching machines in the United States influenced developments in Canada. Arnett, Trout and Clarke (1962) note that some American findings suggest that teaching machines are unnecessary and that some schools in the United States had discontinued using teaching machines because they were found to be unreliable mechanically.

Rutherford (1961) indicates that there were 17 different universities and school systems conducting research and experiments with some method of programmed instruction in 1961. Of the 17 institutions, only 8 indicate that they were using teaching machines and most of these were conducting experiments with only one or two examples. The Faculty of Education of the University of Alberta, for example, was developing a program on statistics to be used on two machines that they were planning to purchase (Rutherford, 1961). At least one of the machines purchased was a Rheem Califone Didak model 501 teaching machine that was no longer in use by 1963 (personal conversations with Dr. S. M. Hunka, University of Alberta). Not all of the experiments with teaching machines used apparatus that was manufactured commercially. Rutherford (1961) notes that one school system used machines devised and fabricated by a teacher. Arnett, Trout and Clarke (1962) report that at least one example of the Koncept-O-Graph teaching machine was purchased by each of the teachers' associations in Alberta, Saskatchewan and Manitoba, to provide, "an opportunity for teachers to visit their central offices to see and try out a simple machine" (p. 16).

While some initial interest in teaching machines was shown by some post-secondary institutions as well as by school systems, it appears that this interest declined, so that few if any were used extensively in Canadian educational institutions. Summarizing the opinions expressed by various Canadian educators, Sorestad (1963) notes that in general there is, "unfavourable reaction to teaching machines; favourable reaction to programmed textbook" (p. 11). In spite of Sorestad's claim of favourable reaction to programmed texts, many educators that contributed to his report indicate that few teachers were using any sort of programmed instruction in their classrooms. From the evidence cited, it may be concluded that the use of teaching machines in Canadian educational institutions was not as extensive or as prolonged as it was in the United States.

Military

It seems that the Canadian military maintained a more cautious position on teaching machines than the American military. The Canadian Armed Forces are also responsible for educating the children of its personnel, so the military administers a number of schools across Canada. Comments by Hack (in Rutherford, 1961) indicate that the use of any sort of programmed instruction was being undertaken on an experimental basis. No mention is made of teaching machines. It appears that scrambled books were used predominantly (Rutherford, 1961). While the Canadian military was aware of teaching machines and programmed instruction, it did not deploy either extensively and it appears to have had less interest in them than most Canadian educational institutions.

Industrial training and the home market

While some relevant literature and information is available concerning such deployment in the United States, similar material about Canada is lacking. It is likely that some

Canadian companies used teaching machines for training purposes, given the influence both of the United States and the United Kingdom.

Although there is a paucity of printed and published information concerned with the sale of teaching machines to the Canadian home market, at least one teaching machine, the E.L.F., is marketed in Canada, in conjunction with sales of encyclopedias (personal correspondence with Mr. L. S. Kozma, November 11, 1990). It is likely, therefore, that some American companies operating in Canada, sell teaching machines to Canadians using similar sales techniques to those used in the United States.

Deployment and use of teaching machines: United Kingdom

Educational institutions and the military

The development of teaching machines in the United Kingdom parallels developments in the United States closely, except that there appears to have been closer coöperation between some educational institutions and branches of the military. While some individuals in the United Kingdom were aware of American teaching machines by the end of the Second World War, it seems that little use was made of teaching machines in most British educational institutions and the military until the early 1960s (Annett, 1964; Stavert, 1967). Initially, most teaching machines had to be imported from the United States. Some companies such as Van Valkenburgh, Nooger and Neville, licensed the production of the Trainer-Tester erasable overlay cards to British companies (Hendershot, 1967). Other companies such as U. S. Industries, opened branch offices in the United Kingdom (Gee, 1963) and further encouraged the use of teaching machines by lending AutoTutor Mark II teaching machines to branches of the military and to some educational institutions (Knight, 1963; Cavanagh, 1964).

Several British companies started to construct and market teaching machines shortly after American machines began to be imported (Gee, 1963; Goodman, 1963; see also Appendix A). Cavanagh (1964) indicates that many educators were reluctant to use teaching machines because they were largely untried and unproven, and because funding to purchase them was not usually available. Before most British educators were willing to use teaching machines, therefore, they had to be shown convincing results from experiments and pilot studies. While the findings of many American studies were available, indicating that teaching machines do function as efficient instructional devices in particular environments, many educators and military administrators in the United Kingdom remained unconvinced, preferring to conduct their own studies. Examples of studies undertaken by the military in the United Kingdom include: Duncan (1964); Knight (1964); Wallis and Wicks (1964); Stavert (1967). Studies conducted by civilian institutions include: Reid (1964); Bannatyne (1966); Leedham (1967); Jenkinson and Browning (1970). In one study, Knight (1964) conducted experiments comparing earlier designs of teaching machines such as the punchboard and the chemocard to more modern linear and branching teaching machines. Most studies recommend further investigation and some conclude that teaching machines should not be deployed generally until results are obtained from longitudinal studies. Knight (1963) for example states, "While it is too early to recommend the large-scale use of teaching machines in all teaching situations, it is not too early to recommend that systematic experimentation should be used..." (p. 48). In spite of such recommendations, some British firms began to manufacture and market teaching machines (see Appendix A).

At least one university used teaching machines experimentally as a part of a program of studies. Owen, Hall and Waller (1964) report that four Grundytutor teaching machines were used at the University of Newcastle upon Tyne to teach aspects of electro-cardiogram analysis to a class of 12 final-year medical students. The authors note that although linear machines were available as well as scrambled books, they selected teaching machines that used a branching-type program because they, "found it more convenient"

(Owen, Hall & Waller, 1964). Favourable reactions were noted from 11 of the 12 participants. Owen, Hall and Waller (1964) conclude only that further testing is required before teaching machines are, "likely to become at least a useful ancillary method in medical education" (p. 65).

While some schools and other educational institutions made particular use of teaching machines, Kemp (1967) states that the use of teaching machines as well as programmed instruction in general was spreading slowly throughout schools. Several reasons are cited by Kemp (1967) to explain the slow spread, including teachers' fear of technology and the high cost of most teaching machines combined with little or no government funding to defray the purchase cost. The poor mechanical reliability of many teaching machines is another probable reason why their use was limited (Annett, 1964b). Unwin and Leedham (1967) state that by 1966, the prevalent view by educators towards teaching machines in the United Kingdom, was that they were largely unnecessary,

> Few contributors appear to make use of, or hold out much hope for, the simple mechanical machine This is in clear contrast to the picture several years ago when such machines were assumed to be of first importance in the presentation of programmes. (p. 23)

These sentiments are also shared by Blake (1970).

Although some teaching machines were manufactured in the United Kingdom, increasing the number of machines available to educators in that country, it appears that use of teaching machines in schools was not widespread. By the end of the 1960s, interest in teaching machines among most British educators and the military was in decline (Thornhill, 1967).

Industrial training and the home market

Accounts from the literature available indicate that the most extensive use of teaching machines in the United Kingdom was within industries. While it is not possible to ascertain the exact date when teaching machines were first used in modern British industries, Austwick (1964) describes one specialized teaching machine that was in use before the 1960s.

The apparatus is a teaching machine that is used to teach one aspect of a specific and complex skill, the joining or *linking* of hosiery material in the factory. The procedure in use at that time entailed moving a special tool in a particular fashion across the pieces of material to be joined. The teaching machine is designed to facilitate the correct movement of the tool over the pieces of hosiery. The device consists of a housing that supports two shaped parallel metal bars that conform to the correct movement of the tool. The tool is simulated by two wooden-handled metal styli that are each connected by a wire to one terminal of a low-voltage power supply. One simulated tool, located to the left of the bars, is intended for use by left-handed individuals. Right-handed individuals use the simulated tool located to the right of the bars. The other end of the power supply is connected to the two metal bars, after first passing through a light and/or buzzer. In operation, one of the simulated tools is used to travel the path between the two bars without touching either bar. Contact between the stylus and either bar completes the electrical circuit, resulting in a feedback signal which indicates to the user that an incorrect movement has been made (Austwick, 1964).

While it seems that this teaching machine was not based intentionally upon any articulated theory of learning, it seems to embody attributes of two early theories. It is noted in Chapter II, that Quintilian fabricated a lettering guide to help teach students the correct movements of the hand, wrist and arm. While not a teaching machine, because it lacked a means of providing feedback, Quintilian's lettering guide endeavored to reduce the complex skill of writing into simpler, discrete tasks. The quintain, however, provides tangible feedback to the user when an incorrect input is made. It appears that the hosiery joining teaching machine combines the complexity reducing feature of Quintilian's device with feedback similar to that provided by the quintain. Other companies used teaching machines that were manufactured commercially.

Austwick (1964) estimates that more than 30 companies were using teaching machines by 1962. Kay, Dodd and Sime (1968) indicate that the use of teaching machines by industry is encouraged through government funding provided through the Industrial Training Act. Some industries in the United Kingdom continue to use teaching machines for particular aspects of training. For example, Phillips (1976) reports that the British Post Office designed a variety of specialized teaching machines to help train personnel in correct operating procedures of new letter and parcel sorting machines. Although it may be contended that teaching machines based on Skinnerian principles are more effective than traditional methods of instruction, Phillips (1976) indicates that the primary reason such machines were used in the Post Office, was that they provided immediate feedback to the user at less cost than conventional training methods.

An accurate account of home sales of teaching machines in the United Kingdom is not possible because of a lack of information.

Deployment and use of teaching machines: Europe

Available information indicates that while some European countries did develop and market their own teaching machines, limited use was made of them in educational institutions, the military and industry. The manufacture and sale of erasable overlay cards was licensed to a French company by Van Valkenburgh, Nooger and Neville (Hendershot, 1967). It is likely, therefore, that some schools, European industries and military agencies as well, used erasable overlay cards for instruction.

Skinner (1983) indicates that by the early 1960s, there was at least one German publication *Lehrmaschinen* (Teaching machines) concerned with the theories and the developments of teaching machines. Later accounts suggest that there was little use made of teaching machines in Germany. Rademacker (1967) notes that while some schools and industries use programmed instruction to some extent, few such institutions used teaching machines. It should be noted that Rademacker (1967) is referring to the use of teaching machines in the areas once known as East and West Germany. Although the Germans were aware of teaching machines, Rademacker (1967) states that few companies desired to manufacture and market them because they, "recognized that they have hardly any chance to sell any machine for which they have no programmes" (p. 196). Rademacker (1967) implies that practicing teachers were not expected or encouraged to design their own programs. The inadequate supply of suitable programs, therefore, likely contributed to the limited use of teaching machines in German educational institutions.

An experimental approach to teaching machines was adopted in Sweden during the early 1960s. Stukat (1964) states that course material in grammar and a teaching machine based on the theories of Skinner was developed and field tested in Sweden between 1961 and 1963. The teaching machine, designated the *PIL*, is a mechanical device contained in a plastic housing, also containing a program printed on a roll of paper (Stukat, 1964; see also Appendix A). After field testing, the teaching machine was made available commercially in Europe and North America (Gille, 1965). There is no information available to indicate how extensively the PIL teaching machine was used in these markets.

Information is scarce concerning the use of teaching machines in Eastern Europe. One account from Hungary suggests that development and use of teaching machines was rudimentary compared with Western Europe, the United Kingdom and North America. Kovács and Terényi (1967) describe an integrated teaching machine system or feedback classroom of their own design. While the authors note that some of their ideas are derived from an awareness of some American teaching machines, the theoretical basis as well as the purpose of their teaching machine differs from most American teaching machines.

Instead of using a device solely to provide instructive feedback to students in response to an input, the apparatus devised by Kovács and Terényi also provides feedback to the instructor concerning the effectiveness of a lecture or lesson. Kovács and Terényi (1967) state, "a teacher can do a great deal of harm, largely because, through no fault of his own, he has no instantaneous knowledge of actual performances of his pupils" (p. 307). By being aware of whether or not the main points of the lecture or lesson are remembered, Kovács and Terényi maintain that a teacher's performance may be improved by altering teaching methods and emphasis on aspects of the subject matter, until uniform satisfactory indications are obtained by the teaching machine.

The apparatus, called the *Didaktomat,* consists of enough four-position switches to enable each student to respond to questions. The switches are connected by wires to a panel that contains a set of small electric bulbs, each student being represented by a single bulb. The panel is located at or near the front of the class, and it is arranged so that the bulbs face the class. The side of the panel facing the instructor houses four multiple-position switches as well as a typewriter that has two keys connected to different electromagnets (Kovács and Terényi, 1967).

In operation, questions for the class are presented individually, either by a slide projector or on a blackboard. The students are instructed to construct a response to the question. After a given period of time, the question is replaced with four possible responses. Each student is then instructed to compare his or her constructed response with the four responses presented and to move the four-position switch to the number or letter of the response that most closely matches their constructed response. While the students are setting their switches, the instructor turns the multiple-position switches on the panel, so that the mechanism will recognize only one position of the students' switches as being correct. The machine is then switched on. The machine is designed so that the only lights that are illuminated are those representing students that have selected the correct multiple-choice response. At the same time, a mechanism within the Didaktomat connects (according to a pre-determined seating order) each student's switch to the electromagnets connected to the typewriter keys. If a student has selected the correct response, then the circuit of one electromagnet is completed. This action causes the key connected to that electromagnet to be pulled down, causing a particular character to be printed on the paper in the typewriter. An incorrect response causes the other electromagnet to pull a different key down, resulting in a different character being printed on the paper (Kovács & Terényi, 1967). The machine is then switched off, the carriage return of the typewriter is moved, so that subsequent responses are recorded on a new line, and the class is presented with the next question. Kovács and Terényi (1967) maintain that both the students and the instructor gain feedback about their respective performance and each may improve, therefore.

Although the Didaktomat was used experimentally in some Hungarian grade schools and in some universities, there is no indication that the Didaktomat was developed commercially or that any other type of teaching machine was used extensively in Hungary. While one might conclude that the development and use of teaching machines in the Eastern Europe of the 1960s was limited because of the prevailing system of government, there is evidence to show that teaching machines were being developed in the Soviet Union at this time.

Deployment and use of teaching machines: Soviet Union

It has been noted previously in this chapter that Skinner and others maintain that it was the apparent superiority of Soviet science and technology, manifest in their launch of Sputnik I, that spurred the development and deployment of teaching machines in the United States. It seems ironic, however, that while some individuals in the United States were advocating the use of teaching machines to enable American schools to catch up to the apparent accomplishments of Soviet education, few teaching machines were either being used or developed in the Soviet Union.

Skinner (1983) claims that educators in the Soviet Union first became interested in teaching machines following his lectures in Moscow and Kiev in 1961. While none of the literature available from the Soviet Union supports Skinner's claim directly, several sources indicate that developments with teaching machines in the Soviet Union began in 1962 (Tikonov, 1970; Plugin, 1970; Landa, 1973). Plugin (1970) claims that Soviet teaching machines are not based upon American models and theories, but instead follow, "a theory based on Marxist-Leninist teachings, which laid the foundation for the new system of programmed instruction" (p. 17). Other Soviet scholars such as Tikonov (1970) and Landa (1973) claim that American theories of learning are inappropriate for Soviet education, because they are derived primarily from theoretical psychological premises rather than being based upon practical observation and a working knowledge of pedagogy. An investigation of the learning theories inherent in Soviet teaching machines, nevertheless, reveals that many Soviet theories of learning resemble theories postulated in Europe and North America. One theory advanced by Gal'perin (1967) for example, reduces the learning process into three main sequences, progressing from the concrete to the abstract. Gal'perin's theory of learning appears to be remarkably similar to a theory advanced by Bruner (1964). Descriptions of types of programs used in teaching machines are also similar to American descriptions, including the names of program types (Rostunov, 1967; Tikonov, 1970). The nomenclature associated with Soviet teaching machines is largely identical to that used in North America. The Russian words used to describe teaching machines are ***обучающие машины***, which translates directly as *teaching machines*. Some works in translation, however, introduce variations in terms without suitable definitions. Plugin (1970) for example, uses the terms *testing machine* and *teaching machine* interchangeably, yet the terms mean different things in North America. Some works in Russian do not use the term *testing machine* (Rostunov, 1967; Tikonov, 1970).

While it is not practical to describe each Soviet teaching machine noted in the literature, descriptions of a few devices might assist the reader in comprehending the direction taken by the Soviets in developing teaching machines. Rostunov (1967) and Plugin (1970) both mention the existence and use of punchcards and special punchboards. Other types of Soviet teaching machines resemble models devised in North America. One example, the OM-7-6 teaching machine is similar in design to the subject matter trainer, except that the Soviet device can be placed on a desk to permit the user to sit while using it (Rostunov, 1967; see also Figure 65). A common system of designation is used to describe most Soviet teaching machines. The prefix *OM* represents the first letters of the words *teaching machine* in Russian. The first numeral in the designation refers to the model, and the last number indicates the version of the model. Other teaching machines are known by names, however.

According to Plugin (1970) one of the most popular teaching machines in the Soviet Union is the device called Ласточка [*Lastochka*]. Tikonov (1970) states that the Lastochka was introduced in 1966 and that approximately 5,000 units were used in Ukraine for unspecified industrial training. It is stated further, that the unit cost of the Lastochka in 1970 was approximately 350 Rubles.

The device consists of a large housing that can hold up to ten cards arranged in two columns of five. Each card contains a question and four possible responses. Four push-buttons located near the base of the housing enable the user to enter his/her selections. Before the machine can be used, the internal mechanism must be set so that only one push-button for each card is registered as correct. Figure 77 (after photographs in Plugin, 1970, p. 20; Tikonov, 1970, p. 94) shows the general external appearance of a Lastochka teaching machine.

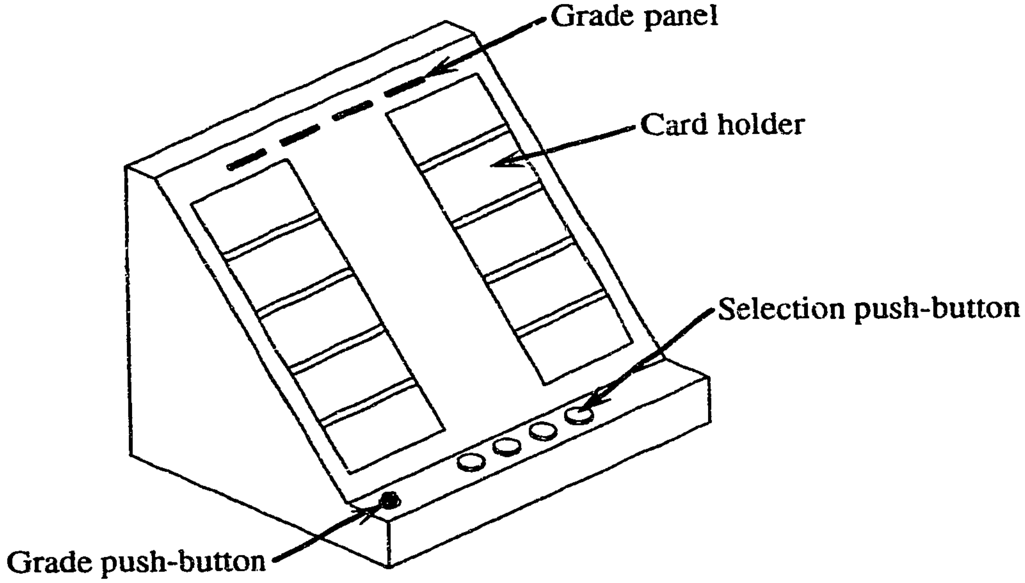


Figure 77. Appearance of a Lastochka teaching machine

To enter responses properly, the user must begin with the card at the top of the left-hand column. Once a response is selected, the appropriate selection push-button is pressed. The user then proceeds down through both columns. When all of the selections are entered, a push-button marked *grade* is pushed. This action causes the machine to illuminate one of four plastic panels located near the top of the housing. If all questions are answered correctly, then the panel containing the word *excellent* is illuminated. Eight correct responses causes the panel containing the word *good* to be illuminated. The *satisfactory* panel is illuminated if only 7 or 6 correct responses have been entered, and the *unsatisfactory* panel is illuminated if 5 or fewer responses are correct (Plugin, 1970).

Another series of teaching machines, including the OM-3 and the OM-9-7, permit both constructed and multiple-choice responses. These teaching machines are similar to some American-made units (see Appendix A). Figure 78 (after illustrations in Rostunov, 1967, p. 52 and Plugin, 1970, p. 22) shows the appearance of an OM-3 teaching machine. This illustration should be compared with Figure 72. By using this particular type of teaching machine, questions can be designed for a constructed response or for a multiple-choice response, selected by punching holes. A simpler version of this type of machine, the OM-9-9, contains a number of cards, each of which contains a question and sufficient space either for a constructed or a selected response. Each card is moved into a collecting bin at the bottom of the housing after each question is completed (Rostunov, 1967). It is likely that another machine is used to score those cards containing punched responses.

Some teaching machines were designed to be used for one particular topic only. One example of this is the complex teaching machine CM-5. This apparatus consists of a housing containing indicator lamps, push-button switches and internal wiring as well as a printed schematic of a pentode vacuum tube, type *ИЛ-12* [IL-12] on the surface of the housing (Rostunov, 1967). Printed representations of wires leading from the schematic pass across a number of octal sockets mounted in the housing. Discs, containing two or more pins, and which have other electronic schematic symbols printed on their tops, are designed to be plugged into the sockets. Each socket is wired to the indicator lamps in a specific fashion. Each disc, when plugged into the correct socket, completes one or more circuits to indicator lamps (Rostunov, 1967). The purpose of this teaching machine is to assist a user in learning the correct placement of components in particular circuits. If the

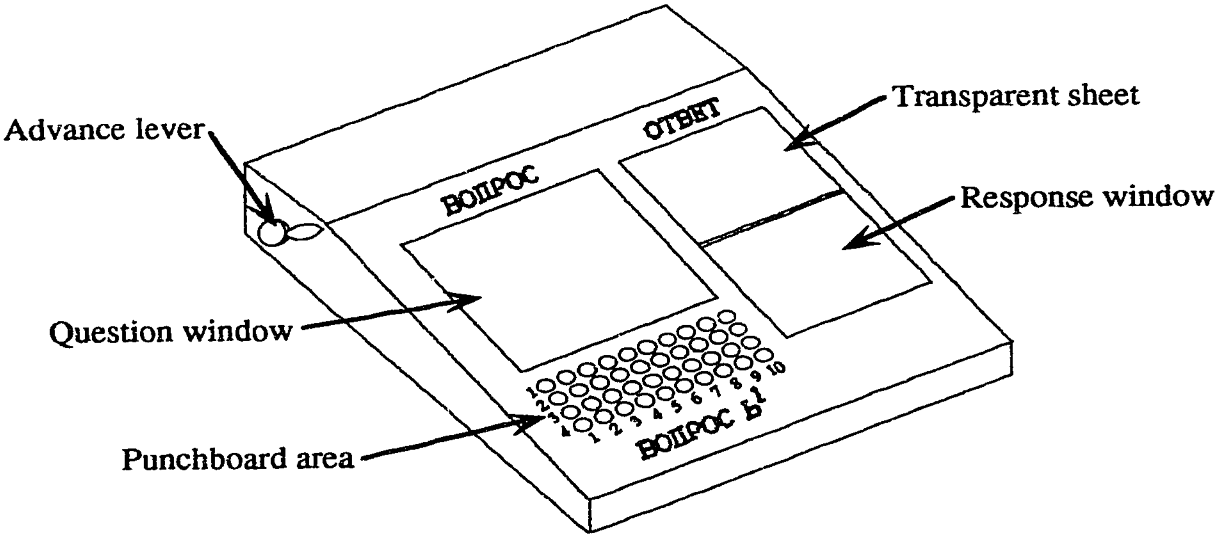


Figure 78. Appearance of an OM-3 teaching machine

user does not place all of the discs into the correct sockets, then the appropriate indicator lights will not be illuminated. By pressing the push-buttons, the machine informs the user as to which parts of the circuit are not functioning correctly. In this manner, rudiments of circuit trouble shooting may be learned. For the apparatus to be effective, the user must possess some knowledge of the particular electronic symbols used as well as knowledge of the characteristics of the components that they represent. The CM-5 teaching machine, while electro-mechanical, is similar in principle to the American Trainer-Tester erasable overlay cards. It is possible, given the information available about the extensive use of the Trainer-Tester cards by the American military, that the predominant users of the CM-5 teaching machine were branches of the Soviet military, although there is no evidence available to substantiate this speculation.

Some machines, such as the OM-9-3, combine audio-visual devices such as film projectors and tape recorders with teaching machines. The OM-9-3 is arranged with an indexed tape recorder and film projector, so that remedial information may be presented to the user when an incorrect response is selected. In this manner, the OM-9-3 teaching machine is similar in operation to the Mentor and Grundytutor teaching machines (see Appendix A) which are based on Crowder's principle of intrinsic programming. Similar teaching machines include the *Гамма-1* [*Gamma-1*] and the *Минчанка* [*Minchanka*]. While the Gamma-1 machine uses indexed film both to present and to control the program, the films used in the Minchanka machine are controlled by special punched cards, installed separately, that depress particular pins and allow other pins to pass through the punched holes. The pins are connected to switches, connected in turn to electric circuits controlling specific functions of the machine. In this manner, the punched cards determine what is presented to the user on the basis of the input. The Minchanka teaching machine is designed both for individualized and group use, where uniform progress through the program by the entire group is desired (Plugin, 1970).

Although some Soviet teaching machines were designed for individualized instruction specifically, it appears that group instruction was preferred. Many Soviet teaching machines are designed to be used in class sets as part of a system, where the progress of each individual is presented on a central panel that is monitored by an instructor. By using teaching machines in this manner, it is contended that the progress of each individual can be kept within a defined acceptable range by the machine and the instructor

(Rostunov, 1967). Plugin (1970) describes such teaching machine systems as *automated classrooms*.

Some automated classrooms or teaching machine systems, are equipped with teaching machines designed for individualized instruction, that have been altered so that they can reveal the progress of the user to the instructor. Examples include the OM-9-5 and the OM-9-7, both of which resemble the OM-3 teaching machine illustrated in Figure 78. Unlike the OM-3, the OM-9-5 and OM-9-7 contain electric circuits and rows and columns of lamps corresponding to holes in the punchboard-like areas of the machines. The corresponding lamp in the array is illuminated whenever the user makes a selection in the punchboard-like area (Rostunov, 1967). Another machine, the OM-9-8, is a remote lamp array that can be connected by special cables to a number of individual OM-9-5 teaching machines (Rostunov, 1967). In the ways just described, a single instructor is able to monitor the progress of several students simultaneously.

As early as 1963, automated classroom systems were designed in the Soviet Union that employ a central teaching machine with remote input devices and feedback indicators located at individual desks (Tikonov, 1970). Many such class-sized teaching machines were produced under the name *Аккорд* [*Akkord*] or the AK series, the AK representing the first letters of the Russian words *Автоматизированный Класс* [*Automated Class*] (Rostunov, 1967). There is a range of sophistication and complexity among the different varieties of Soviet automated class-type teaching machines. Some examples, such as the AK-6 and the AK-8, consist only of switches to permit individuals to enter responses, an instructor console with counter for correct and incorrect responses, and indicator lights to provide feedback to each individual (Rostunov, 1967). More complex examples include the Akkord, which can control the progress of each individual through modified linear programs (Tikonov, 1970). The SKM-4 system not only performs the activities of the systems already mentioned, but it can also control the movement of window shades and activate selected pieces of audio-visual equipment (Plugin, 1970).

Although some Soviet teaching machines were developed further than some American teaching machines, there are indications that Soviet models were no more successful ultimately than their North American and European counterparts. Tikonov (1970) states that the Akkord teaching machine system was used experimentally in a school between 1963 and 1968. There is no indication that the Akkord was distributed subsequently for general use. Expense is a factor that likely restricted the deployment of such complex teaching machine systems. Plugin (1970) states that Soviet teaching machines in general possess several inherent disadvantages, "complexity of design, unwieldy size, a low operational reliability factor, high cost of production, impossibility of developing one by individual efforts, and the need for specially equipped auditoriums and qualified technical service" (p. 26). Zender (1975) contends that the simultaneous development of Computer Assisted Instruction in the Soviet Union and its support by the military rendered teaching machines obsolete by the mid 1960s. Contemporary literature concerned with education in the Soviet Union notes the use of computers, but not teaching machines. The absence of references to teaching machines suggests that their use has either been reduced or eliminated.

Deployment and use of teaching machines: Japan

Although there is little information available to show whether or not the Japanese have used teaching machines in either the home market or in industry, there is some information available about the use of teaching machines in Japanese education.

It is noted in the previous section that Zender (1975) attributes the demise of teaching machines in the Soviet Union to the advent of Computer Assisted Instruction. In a similar vein, Suetake (1972) indicates that CAI contributed to the development and use of teaching machines in Japan. It does not appear that Japanese educators expressed much interest in either North American or European teaching machines marketed in the early 1960s, during the so-called teaching machine movement. Some Japanese educators were aware of various CAI systems, but it is noted that few schools in Japan could afford them (Suetake, 1972). To enable schools to increase their efficiency and to otherwise avail themselves of technological innovations in education, several Japanese educators endeavored to produce inexpensive electro-mechanical machines that could be used in most schools (Suetake, 1972).

Many of the devices are not teaching machines, but teaching aids. For example, a device called the *Ripple Tank*, devised by Oshina, is intended to be placed on an overhead projector to demonstrate wave mechanics (Suetake, 1972). Some devices noted are teaching machines according to the definition of the term provided in Chapter I. Most of these devices, while designed by Japanese, are similar to North American, European and Soviet teaching machines described previously. This similarity may in part be explained by noting that some designers of Japanese teaching machines are not educators, but are employees of corporations (Suetake, 1972). Some Japanese teaching machines include: a pattern recognition device called the *Pattern Recognition Teaching Machine for Children*, which is similar to the Rheem Califone Didak 101 (see Figure 72); an electric punchboard apparatus called the *Simple Learning Machine*, devised and marketed by the Sankyoseiki Company; a device called *Masking the Slide*, which is similar in operation to Miesegaes' question and answer device (see Figure 67); and a push-button response device called *Touch and Learn*, described as *unique* (Suetake, 1972).

While it appears that some of these teaching machines were used in several levels of Japanese schools, there is little examination of the underlying theories of these machines. Instead, the teaching machines are considered to be adjunct aids for the teacher (Suetake, 1972). Information is not available to show whether or not teaching machines continue to be used in Japanese schools. It is clear, however, that the factor of cost was significant in determining what sort of technological changes occurred in many Japanese classrooms.

Factors affecting use and conclusions

Many different teaching machines have been described in this chapter. Some are merely experimental versions based upon some theory or pedagogical approach that were applied to education in general, while other teaching machines were devised to address some perceived need. Most of the teaching machines described are no longer in production, yet a few continue to be manufactured and used in particular environments. It is also important to note that computerized teaching machines, such as *Speak and Spell* continue to be manufactured and sold primarily to the home market. Computer-based teaching machines will be described and discussed in Chapter VII. From what has been presented in this chapter, it is reasonable to conclude that there are many factors that contribute both to the use and to the ultimate fate of teaching machines. While it might be easy to attribute the demise of many teaching machines to obsolescence, this chapter has revealed other factors that contribute both to the success and the failure of teaching machines.

It is clear that two of the biggest factors concerned with teaching machines are cost and pedagogical suitability and effectiveness. Other factors such as the perceived potential market, societal and political perceptions of education, reliability of equipment, and the availability of suitable course materials to use with the devices, all affect whether a particular device or a class of devices continues to be used or is abandoned. Cost appears to be the overriding factor, nevertheless. Without the required amount of funds, no educational institution, business, government or private individual can acquire teaching machines and the appropriate course materials. The commercial failure of the Pressey Testing Machine, as well as the inability of some innovations to reach the market because of market saturation, illustrate how both large and small economic conditions can effect the production and the use of teaching machines. Similarly, the use of teaching machines in Japan rather than technologically superior computers, illustrates further that cost is a significant factor in determining what type of instructional device, if any, is used.

Pedagogical suitability and effectiveness appears to be another significant factor. LaZerte discontinued the development of his problem cylinder because his experimental findings indicated that the device added to the difficulty of learning the intended subject matter. The effectiveness of other teaching machines was of concern to many educators. Almost immediately following their invention, Skinner endeavored to demonstrate that his design of teaching machines were superior pedagogically to other methods of instruction (Skinner, 1958; 1961b). Other studies were also undertaken, and many of these demonstrate the apparent superior efficacy of teaching machines. Examples include: Ferster and Sapon (1958); Stolurow (1961); Holland (1962); Fine (1962); Roth (1963). Some of these studies are marred by faulty analyses and by faulty elements of the experiments themselves. One example is a study by Coulson and Silberman (1959a). The authors describe an experiment comparing rates of learning between different methods of instruction using teaching machines. Mock-ups of teaching machines are used instead of actual devices, with a human being inside the mock-up performing the functions that a real teaching machine would perform. Coulson and Silberman (1959a) explain that they used mock teaching machines, "for the purposes of convenience" (p. 5). What is one to conclude from a study that does not use actual teaching machines because they are not convenient? While mock teaching machines facilitate changes to the method of presentation, studies that use them cannot provide any data about mechanical reliability. Although not all experimental studies comparing the effectiveness of teaching machines and programmed instruction to other methods of instruction are conducted in the same manner as the study by Coulson and Silberman (1959a) the findings of experimental studies conducted in an environment controlled largely by the experimenter cannot always be applied to a classroom. Gagné and Bolles (1959) state, "much of the experimental research has been directed toward testing theoretical points which have little immediate practical application" (p. 13). Quackenbush (1961) notes that there is a wide variation in the definition of terms between studies, so it is not always apparent if the conclusions of a particular study indicate whether the use of teaching machines is actually more efficacious than other methods of instruction. Although some educators were evidently willing to use teaching machines without considering this factor, others were not willing to use them until additional, clear evidence was produced. Summarizing the general sentiments expressed by Canadian educators at a conference, Sorestad (1963) states, "Unless more scientific experimentation is organized and carried out there is very little possibility of making any worthwhile assessment [either of teaching machines or programmed instruction in general]" (p. 12).

A complaint found in many articles about teaching machines is that program materials were either lacking, inappropriate or superfluous. Previous sections of this chapter note the concern expressed by some individuals about the lack of programs for teaching machines. Gilbert (1979) reports that some programs which were available had no market because they were not appropriate to any curriculum. Perhaps worse, is the claim by Foltz (1961) that many programs are restricted in their scope by the constraints imposed by the machines they are designed for.

Several authors including Goebel (1961); Pressey (1964a); and Gilbert (1979) all state that much of what is presented by expensive and sometimes elaborate teaching machines, can be presented as effectively by using either simpler, less expensive machines or books. Finn and Perrin (1962) as well as Gilbert (1979) indicate that teaching machines are sometimes nothing more than "mechanical page turners", implying that teaching machines are largely superfluous. According to Finn and Perrin (1962) one effect of this view of teaching machines is that they are perceived as gadgets. Goebel (1961) a research psychologist for the United States Air Force, condemns most teaching machines as being "expensive gadgets" and instead advocates the use of simple machines or printed texts. The failure of teaching machines in general to address educational needs and to be effective pedagogically, as perceived by teachers, were factors that limited the development and the deployment of teaching machines.

Concerns about the mechanical reliability of teaching machines are mentioned in previous sections of this chapter. Moreover, it is noted that mechanical reliability was a concern not only in North America and Europe, but in the Soviet Union as well. The complexity of some teaching machines and their consequent predilection to operational failure prompted some individuals to denounce them aggressively. Gilbert (1979) states that in an address given in 1960 to a convention of the American Psychological Association, he remarked, "If you don't have a device called a teaching machine, don't get one. Don't buy one, don't borrow one, don't steal one. If you have such a device, get rid of it. Don't give it away, because someone else might use it" (p. 16). It is likely that such extreme criticism of teaching machines affected the extent to which they were deployed.

Others, such as Soles (1963) contend that many teaching machines were manufactured simply because particular businesses considered teaching machines to be a means to exploit the market of education. There are many educators who contend that it was commercial exploitation that ruined the potential of having teaching machines become a *necessary tool* in schools (Foltz, 1961; Finn & Perrin, 1962).

Societal and political perceptions of education affected the status of teaching machines. The advent of the National Defence Education Act in the United States, reflected political attention to the development of teaching machines in the interest of improving the efficacy of education. There was little experimental evidence at the time it was introduced to establish that using teaching machines in schools would result in better education, or that Soviet education, which some believed to be responsible for that country's launch of a space vehicle before the United States, was superior to American education. Several individuals including Skinner (1986) maintain that the use of teaching machines was impeded and ruined ultimately by teachers who were afraid that teaching machines might eliminate the need for teachers. Although some individuals such as Broudy (1962) contend that teaching machines may replace teachers, others such as Fine (1962) and Sorestad (1963) state that teaching machines are not mechanically reliable or complex enough to accomplish the displacement of the teacher. While the fear of replacement by a machine may well have impeded some use of teaching machines, there were other educators who promoted the use of teaching machines because of social considerations primarily. The California Superintendent of Public Instruction, as quoted by Fine (1962) indicates that schools should use teaching machines because many parents appear to be buying them. The so-called ***band-wagon effect*** also appears to be a factor contributing to the development and the demise of teaching machines. Figure 75 illustrates graphically the changes in interest in teaching machines and in programmed instruction in general. These changes coincide with changes in the number of commercial enterprises producing and marketing teaching machines for educational institutions. Moreover, Jonassen (1987) states that the decline of the teaching machine movement as well as interest in programmed instruction occurred while, "the newest bandwagon in education, computer-assisted instruction, was gathering steam" (p. 279).

From what has been described and discussed in this chapter, it is clear that many factors in addition to theoretical and pedagogical considerations affected both the development and the deployment of teaching machines throughout most of the world. Factors that affect teaching aids in similar ways are noted in previous chapters. A further consideration of the factors affecting instructional devices in general will be found in Chapter IX. The idea of using mechanized devices for instruction has not disappeared, however, since many computer-controlled devices are used in schools as well as in the military and industry. Developments of computer-controlled instructional devices will be described and discussed in the next chapter.

Chapter VII

Computers as instructional devices

Introduction and antecedent developments

It is contended by some educators such as Suppes (1966), Hilgard (1971), Bork (1981), Collis and Muir (1984), Alessi and Trollip (1985), Bishop (1986), Benjamin (1988), Niemiec and Walberg (1989) that the use of computers as instructional devices is a novel phenomenon of the second half of the twentieth century. While this contention is widespread, it is erroneous since computers were used as instructional devices in earlier times. Although unequivocal proof is lacking, it may be argued that the Antikythera mechanism described in chapter II is both an analogue computer (Williams, 1985) and some sort of instructional device. If this is so, then the Antikythera mechanism represents one of the first uses of computers for instruction.

More convincing evidence to show that computers were used as instructional devices before the twentieth century is found in Chapter IV, in the sections describing Jevons' logical machine. It is clear that the apparatus was designed primarily for instructional purposes. Given this established antecedent use of computers, it may be asked why they did not receive widespread consideration as instructional devices until the second half of the twentieth century.

As cited in chapter IV, Jevons himself notes that there was little practical use for Boolean algebra during the 1870s. There was likely little perceived need for such an instructional device, therefore. Also, his machine was limited in its capabilities by available technology. Given these circumstances, it appears that computers would not be used extensively as instructional devices until a need for them could be demonstrated and until technology permitted them to be more reliable and flexible in operation. Although Augarten (1984), and Williams (1985) both note that analogue devices were developed for performing arithmetic calculations, such devices were neither designed for or used widely for instructional purposes. Later developments in computer technology led to the production of devices that could be adapted to many practical problems.

The first demonstrations of this feature did not occur in education, but in the military for decoding enemy communications. Interest in decoding military communications increased during the 1930s, and reached a zenith in the years immediately prior to the outbreak of the Second World War. The job of cryptanalysts was compounded because the German armed forces used an electro-mechanical device called *Enigma* both to encode and decode their messages. Most Enigma machines contain: a number of rotating wheels or contact disks that are designed to be set by hand; an electrical plug board; an array of lamps; a battery and a keyboard. By rotating each wheel and adjusting the positions of plugs in the plug board, different electrical circuits are made between individual keys and lamps. In these ways, an Enigma machine is capable of generating many thousands of unique codes (Garlinski, 1979). To decrypt messages, therefore, it is necessary either to know the positions of the wheels and plugs on the machine that encrypted the message, or to devise a means to ascertain their placement at the time the message was encrypted. To perform the latter action, what is required is a means to test every possible combination, remember which ones are tried and found to be incorrect, and be able to recognize the correct combination when found. The large number of permutations possible with most Enigma machines means that the aforementioned requirements likely exceed the capabilities of most individuals. It was soon discovered that a machine could perform the functions of de-encryption. Machines of this sort that contain: a method of input; a central processor where the input interacts with the program controlling the operation of the machine; a memory to store a program of operation and the results of interaction with the input; and a means of output, may be called a *computer*. The first such devices used for decryption were electro-mechanical analogue machines that operated slowly and which were not always accurate (Garlinski, 1979). By 1943, the British developed an electronic device called *Colossus*. Besides being much faster than the electro-mechanical analogue devices, Colossus operated according to principles of Boolean algebra, in a manner similar to Jevons' logical machine (Randell, 1980). By designing an appropriate Boolean expression, it was possible for Colossus to decode many messages encoded by Enigma machines.

The versatility of the computer to solve diverse problems was soon recognized. Wiener (1948) contends that branches of the Allied military were aware that the speed of many aircraft rendered obsolete the manual methods of firing anti-aircraft guns. It was realized during the Second World War, that a computer could be used to control anti-aircraft guns, since computers are capable of rapid calculations based both on a program and upon the input provided either by radar or by human being. By their design, computers may also control whatever device is connected or *interfaced* to the output, the movement and firing of anti-aircraft guns in this instance. Moreover, it was discovered by 19[illegible]. that the principles of Boolean algebra combined with the speed of electronic computers and their ability to be connected to a multitude of output devices, enable them to reproduce actual situations artificially. In other words, computers can be used to simulate particular conditions or operations. One of the first computers designed for this purpose was the American *Whirlwind* (Everett, 1980).

Conceived of by the United States Navy, Whirlwind was intended initially to control an aircraft trainer-analyzer, which consisted of a realistic cockpit enclosed in a scaled-down version of an actual aircraft. The purpose of the trainer was to test the characteristics of particular aircraft and to train pilots without the dangers of potential loss of life and/or equipment (Augarten, 1984). Unwittingly, the military had returned digital computers to education, from whence they came. The specialized computer-controlled devices known as simulators will be discussed in chapter VIII.

Predominant groups influencing deployment

Confusion may exist when considering the origins, similarities and the differences between teaching machines and computer-controlled instructional devices. While some accounts consider teaching machines separately from computer-controlled devices (Lumsdaine & Glaser, 1960), some individuals who designed such apparatus refer to them as teaching machines (Pask, 1958; Coulson, 1960). Referring to computer-controlled instructional devices in this way may seem to indicate that they evolved from the teaching machines of the late 1950s and the early 1960s. While it is possible to show how some computer-controlled instructional devices produced during this period did arise from teaching machines and the theory of programmed instruction, there is evidence indicating that many other computer-controlled instructional devices were developed from other theoretical bases and disciplines.

It is evident that there are 4 major groups, identified and discerned by their different theoretical bases and practical backgrounds, that influenced the development of computers as instructional devices in education. Not all of these groups are concerned primarily with education, however. The four groups are:

1) *Computing Scientists*, those individuals concerned primarily with the design of computers and computer systems from the basis of cybernetic theory;
2) Advocates of *programmed instruction*, educators who follow the principles of Skinnerian behaviorism and who perceive any instructional device solely as a means of implementing methods of pedagogy derived from this theory of learning;
3) *Computing hardware Engineers*, individuals skilled in the fabrication of new computers or component configurations from the basis of electrical and electronic engineering;

4) *Computing Educators*, individuals with a practical knowledge of pedagogy, but who also possess a knowledge both of computing science and computing hardware design.

Although four discrete groups are presented, it will be seen that most of the groups influenced each other and work together on occasion, so the distinction between the groups is not always clear. This crossflow of ideas and knowledge notwithstanding, it is also evident that at particular times, one group or another has held predominant influence upon the general design and application of computer-controlled instructional devices.

Early computer-controlled instructional devices

Pask's adaptive machines

Some of the earliest computer-controlled instructional devices produced in the twentieth century were devised by Gordon Pask of the United Kingdom and his associates, beginning in 1953 (Lewis & Pask, 1965). Most of these machines were designed either for military or for specific civilian industrial training purposes. Although Pask worked primarily within his own company, he received much financial support from military agencies of both the United Kingdom and the United States (Pask, 1966).

While Pask later explained the operation of his machines within the context of some popular theories of learning, he did not design his machines explicitly from any of these theories. Instead, Lewis and Pask (1965) state that the devices were, "formulated within the framework of artificial intelligence theory" (p. 220). What is meant by "artificial intelligence" is elucidated by Pask (1966) describing why he became interested in applying computers to instruction, "I became intrigued by conversations and their logical essence in the mechanized (and non-verbal) interaction between a man and a suitable computing machine" (p. 1).

What Pask designed was a number of computer-controlled machines that function not only in a manner similar to some teaching machines described in Chapter VI, but which may also react to each input by presenting either simpler or more complex material and by altering the speed at which subsequent questions and information are presented to the user. These computer-controlled teaching machines, referred to by Pask variously as *adaptive machines* (1960) or as teaching machines (1958) bear little resemblance to the teaching machines described in Chapter VI. Although many of Pask's machines are capable of operating according to the program types of Skinnerian-based teaching machines, many of Pask's computer-based machines are able to function according to the principles of *fuzzy operations*. According to Pask (1975) fuzzy operations entail the ability of a machine to accept a range of inputs for a particular question, and then proceed on the basis of the particular input selected. While some branching teaching machines such as Crowder's AutoTutor alter the sequence of material presented to the user, the machines are not designed to contend with subject matter that might not have only one correct response. Fixed-program machines, therefore, are usually inappropriate for subject matter that may have answers that are partially correct. Such machines also have limited means of error analysis, so it is not apparent to the mechanism whether an incorrect selection of a response is the result of misunderstanding the material hitherto presented, or whether the wrong push-button was either pressed accidentally or pressed because the user was bored with the program. Remedial information is usually presented after a single incorrect response is made, whether it is appropriate or not (Lewis & Pask, 1965). Also, if the remedial information presented does not assist the student, the machine usually continues through its program, oblivious to the plight and the frustration of the user. In these ways, fixed-program teaching machines are limited both in their application and in their appropriateness to individual learner differences. By designing a machine that responds to each input dynamically, by comparing that input to the accuracy of previous responses and adjusting subsequent information accordingly, Pask did not have to contend with the limitations of error analysis inherent in the mechanical and electro-mechanical teaching machines common at that time. Moreover, Pask (1960) differentiates his machines from Skinnerian-type teaching machines in other ways,

> Some teaching machines are tools, logically comparable to a desk calculator or a visual aid. Others, where a feedback is taken from the subject, are tools which are modified by use. An adaptive machine aims to be more than this — it aims to be an extension of the subject's brain. (p. 350)

In this manner, Pask contends that his adaptive machines may also be used to study the functioning of the human mind in the context of cognitive operations and learning (Lewis & Pask, 1965; Pask, 1975). It is clear that few mechanical and electro-mechanical devices are capable of such complex operations, although Pressey and later Crowder made attempts at incorporating elements of error analysis in their teaching machines.

As noted at the outset of this chapter, computers are capable of performing elaborate operations that would not otherwise be feasible. Pask (1958) indicates that most of his early adaptive machines are controlled by analogue computers. While it might appear that Pask was reverting to an obsolete technology, since digital computers were being used for some applications by this time, it must be noted that most electronic digital computers of this period were enormous machines because of the large number of vacuum tubes required for them. The cost of such computers was also high, consequently. Many analogue computers use smaller, less expensive components such as resistors and capacitors. By keeping the use of vacuum tubes to a minimum by using other discrete components, Pask was able to construct small, yet effective computers.

One of the first adaptive machines that Pask and his associates marketed commercially, is a device known as SAKI. This acronym stood initially for *Solartron Adaptive Keyboard Instructor* (Pask, 1959; 1982). Cavanagh (1964) notes that by the mid 1960s, the meaning of the acronym was changed to *Self-organising Automatic Keyboard Instructor*. Both names refer to a number of similar computer-controlled devices designed to teach correct psychomotor skills in the operation of particular keyboard types (Pask, 1982). The machines are also intended to increase speed and accuracy simultaneously, so that the user becomes proficient in both skills at once. Pask (1982) reports that production of the SAKI began in 1956 and that versions were available commercially by 1960.

One of the first SAKI models made available commercially, was designed to teach individuals in industries and government agencies the correct use of a 12-key Hollerith-type keypunch machine (Pask, 1982). This SAKI apparatus consists of a special keyboard connected electrically by a cable to a cabinet housing the computer. Another cable connects the computer to a different cabinet containing an array of lamps and a holder for specially printed strips of translucent or transparent plastic (Pask, 1958). Figure 79 (after photographs in Pask, 1958; 1982) shows the main components of a SAKI computer-controlled teaching machine for keypunching.

The operation of the apparatus is controlled by the computer, referred to as the central processor unit in Figure 79. To use the device, the computer is first prepared for a particular sequence of exercises by installing or modifying hard-wired circuits, and also by installing the corresponding transparent or translucent panel in the stimulus and guidance unit. A matrix of lamps located behind the panel permit the illumination of individual characters on the panel. To begin using the apparatus, the character at the upper left-hand side of the top row is illuminated. The learner is expected to press the key on the keyboard corresponding to that character. To help the learner identify the correct key, a prompting lamp located below the transparent strip is also illuminated. The lamp illuminated represents the position of the correct key on the keyboard. In this manner, the learner is shown the position of the correct key immediately, thereby encouraging the learner not to press an incorrect key first. This feature is particularly important according to the theory of one-trial learning postulated by Edwin Guthrie (1886-1959). Unlike

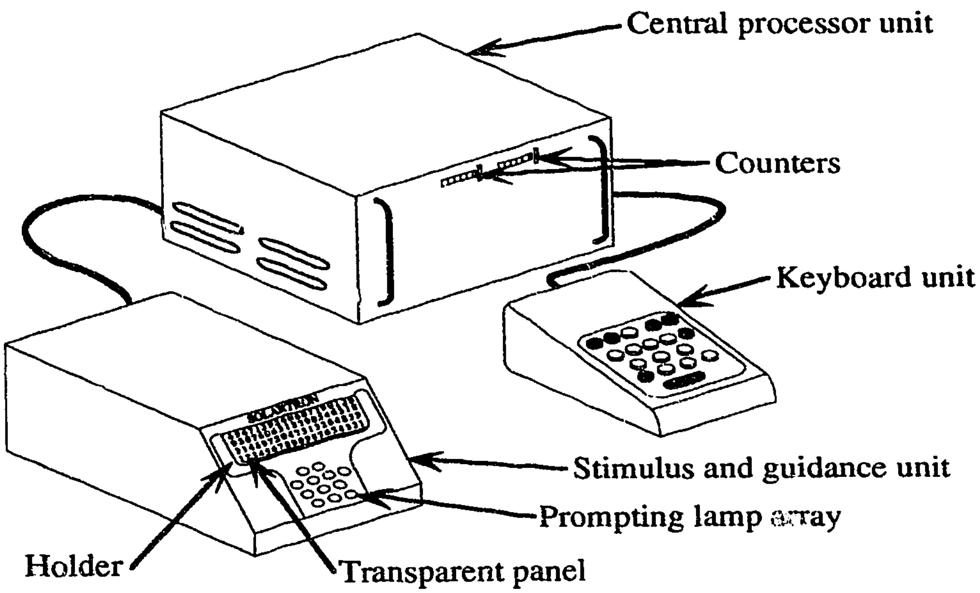


Figure 79. Main components of a Solartron Adaptive Keyboard Instructor (SAKI)

Thorndike's early support of the *law of exercise* (see Chapter V) Guthrie (1942) states, "A stimulus pattern gains its full associative strength on the occasion of its first pairing with a response" (p. 30). While it is not certain if Pask designed the SAKI with this theory of learning in mind, it is apparent that he desired the learner to press the correct key initially. Pask's method of using prompting lamps also reduces the likelihood that the learner will develop the undesirable habit of looking at the keys to ascertain the correct key to press. While Lewis and Pask (1965) claim that SAKI was designed principally from the basis of artificial intelligence theory, it is apparent that Pask was, nevertheless, aware of the pedagogical problem of how a poorly designed learning environment results in the learner acquiring not only the intended skills, but also undesired habits or psychomotor actions that will have to be suppressed or *unlearned* subsequently. From this awareness, the SAKI was designed to limit the number of psychomotor activities of the learner.

If the correct key is pressed, then the computer will darken the first character of the transparent panel. The next character in the row is then illuminated. The corresponding prompting lamp is also illuminated. Capacitors within the computer serve as storage devices both for the responses of the learner as well as for the time interval taken to press the correct key once a character is illuminated (Pask, 1982). The values for these variables are represented by voltages stored in the capacitors. By using comparative analogue circuitry, the computer is able to ascertain not only if a correct key is pressed, but it is also able to compare the time taken by the learner to press the correct key against a programmed *ideal* time interval, represented by a particular voltage in a circuit within the computer (Pask, 1958). The operation of the apparatus usually continues in the manner just described until the learner presses correct keys a set number of times. At this juncture, the computer will gradually increase the speed at which it illuminates particular characters, either repeating the row just completed, or beginning with a different row. The computer also eliminates the prompting lamps by dimming them gradually. When mistakes occur, the computer reduces the speed at which it illuminates characters and it may also re-introduce the illumination of the prompting lamps, depending upon the elapsed time between presentation of the stimulus and the entry of the correct response by the learner (Pask, 1982). Some versions of SAKI were equipped with counters (see

Figure 79) to record the number of incorrect key presses and the number of correct key presses.

By designing a machine that interacts with the learner dynamically, thus both monitoring and controlling particular psychomotor actions, Pask devised an automatic method whereby two distinct psychomotor skills, accuracy and speed, could be taught in immediate succession without the necessity of intervention by a human instructor. An implicit assumption in the design of the apparatus, however, is that the learner already possesses knowledge of correct hand position on the keys. If this knowledge is not already present, it is possible that the learner will employ a technique that is not considered appropriate and which may hinder the development of speed.

Pask (1982) reports that manufacturing rights for the SAKI were purchased by Cybernetic Developments in 1961, and that approximately 50 units were either sold or leased. While some educators mention the SAKI (Fry, Bryan and Rigney, 1960; Stolurow, 1961) it was not intended for schools in general. Lewis and Pask (1965) state. "These devices are not particularly well known in educational circles because they [the devices] have been concerned mostly with teaching of skills found in commerce, industry, and the armed services" (p. 241). Although Pask (1982) contends that the SAKI addressed evident needs in these areas, he notes that some customers did not use the machines for their intended purpose, "The main impediment to marketing the equipment was ensuring its actual use as a training device, rather than an occasionally exhibited status symbol" (p. 72). Sales of the SAKI continued, and by the early 1980s a microprocessor-based digital version replaced the older analogue models (Pask, 1982).

A manufacturing and marketing arrangement had also been made with the Rheem Manufacturing Company of the United States (Foltz, 1961). Their device was known as the *Didak 1001 Psychomotor Skill Trainer* (Fry, Bryan and Rigney, 1960). While similar in principle to the Solartron unit depicted in Figure 79, the Rheem model consists of a console housing all components. The Didak 1001 was equipped with an IBM-type keypunch keyboard, rather than the smaller Hollerith-type keyboard supplied with the SAKI. Figure 80 (after photographs in Finn & Perrin, 1962, p. 47; Fry, 1963, p. 35) depicts the general appearance of the Didak 1001 Psychomotor Skill Trainer.

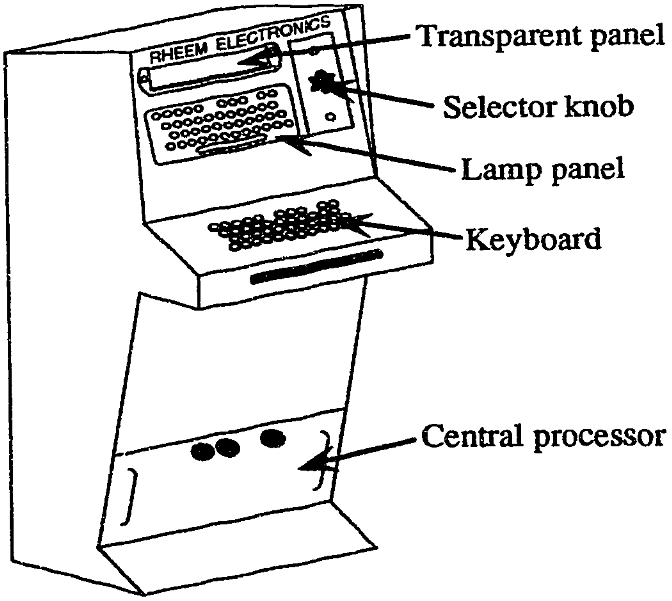


Figure 80. Appearance of Rheem Didak 1001 Psychomotor Skill Trainer

The operation of the Didak 1001 was likely similar to the SAKI version described previously, although the Didak unit possesses a selector knob to allow the selection of a particular exercise pattern from a number available. While the device is described by Fry, Bryan and Rigney (1960) and a photograph of it appears in Finn and Perrin (1962) no price is given in either account. Subsequent catalogues of teaching machines and other instructional devices do not list the Didak 1001 at all. As well, Pask does not mention the device in subsequent works. It is possible, therefore, that the unit was never marketed and that only a prototype was constructed for advertising purposes. This marketing strategy was used by Rheem and other manufacturers of teaching machines to ascertain interest in a proposed product (see Chapter VI).

Pask and his associates designed other computer-controlled adaptive machines for specific psychomotor tasks in industry and the military. Such machines include apparatus to teach fault diagnosis or trouble-shooting in electric and electronic circuits (Pask, 1966). Like the simpler tab items mentioned in Chapter VI, Pask's computer-controlled adaptive machines provide feedback to the user on the appropriateness of the fault-finding strategy used. Unlike the tab items, however, adaptive machines may alter the level of difficulty on the basis of the inputs made by the user and/or the time taken to make a diagnosis of the problem (Pask, 1966). It appears that none of these later adaptive machines were marketed generally or made available to educators in schools (Pask, 1982).

Although Pask (1966) indicates that he and his colleagues worked with and designed computer-controlled instructional devices to study both learning and possible ways in which the human brain functions, most of the apparatus produced has been applied to single-task or *dedicated* applications outside the field of public or general education. The reason for this is explained from the context of initial findings with early experimental models of computer-controlled adaptive teaching machines. Lewis and Pask (1965) indicate that the type of human/machine interaction capable with the early apparatus, "suggested that such machines were not particularly suitable for instruction of intellectual subjects. And the different display characteristics of each new model encouraged the belief that every skill required its own special-purpose machine" (p. 241). While Lewis and Pask (1965) state that subsequent research and developments indicate, "that adaptive machines can be built to instruct *any* subject matter that can be broken down into logically tractable stages" (p. 242) the authors also note that the main reasons why dedicated machines for industrial and military applications were developed and manufactured were economic. Lewis and Pask (1965) state,

> The truth of the matter is that limited financial resources made it desirable to concentrate, initially, on the production of simple special-purpose devices that were likely to have immediate impact ... to convince an unreceptive public of the generality of the methods advocated. (p. 241)

Unlike Skinner, who promoted his mechanical teaching machines before all of the technological problems had been resolved satisfactorily, Pask (1960) realized that his computer-controlled teaching machines possessed technological as well as pedagogical limitations and promoting such *constrained devices* could possibly jeopardize the later deployment of more effective and appropriate instructional devices. Pask (1960) states that his research, "upon other applications of the self-organizing system led to electrochemical artifacts which may in a few years, be practical and far less cumbersome teach-realm of computing science and cybernetics, or whether theories of learning influenced the design and development of these machines.

Relationship to theories of learning

While Lewis and Pask (1965) note that the SAKI and other adaptive machines were designed on the basis of artificial intelligence theory, Pask (1975) contends that such machines are cognitive systems congruent with cognitive theories of learning. Although this contention appears to be valid for some of Pask's experimental devices, it does not seem to be applicable to the SAKI, since the purpose of that device is to modify or *shape* a particular behavior or *emitted response* of the learner. Pask (1975) clarifies this apparent disparity by stating that many of the early machines devised, including the SAKI, "were made when behaviourism, of rather a strict and narrow variety, was rampant. As a result, they [the machines] are coloured by this philosophy" (p. 100). As an example of how behaviorism influenced the design of his early machines, Pask (1958) states that, "Teaching is a special sort of conversation directed initially at finding out how the trainee learns and later directed at persuading the trainee to behave in a way that satisfies the employer" (p. 340). Although the influence of Skinnerian behaviorism is apparent here, later elucidations of the underlying theory of learning inherent in these machines reveal that Pask was not following the tenets of behaviorism exclusively.

Unlike Skinnerian-based machines that tend to follow either a rigid linear program or one that is somewhat flexible, such as the branching programs used in Crowder's machines, Pask maintains that to be effective, the actions of the teacher must contend with the peculiarities of the individual learner. Such individual differences include diverse rates of assimilating information and difficulties with specific aspects of the subject being presented. In other words, Pask (1975) states, "learning entails a *teacher who learns...* Any theory of learning in the preferred sense is a theory of teaching, and vice versa" (p. 129). In consequence of this view, Pask (1975) states that his machines, "did not behave in a narrowly behaviouristic fashion. In fact, they exhibited many of the tricks (fuzzy computation, for example) that are introduced more deliberately in our later work" (p. 100). Moreover, Lewis and Pask (1965) maintain that simply altering the behavior of the machine to make it congruent with the behavior of the learner is insufficient. The authors state, "The machine must hold the man's interest. It must provide him with things to do and to think about. Otherwise his attention wanders, and the machine cannot be guaranteed to achieve anything at all" (p. 215). It follows that if such a machine is to retain the attention of the learner, it cannot follow a strictly linear path or even one that provides only a small number of remedial steps or deviations from the path to the intended goal. Pask (1958) maintains that for a machine to hold attention and to motivate the learner, it must react immediately and appropriately to changes in the way the learner responds to the information and questions presented by the machine, "Thus the model in the teaching machine is really a representation of the trainee's ideas of difficulty" (p. 343).

Lewis and Pask (1965) contend that this aspect of the learning theory underlying adaptive machines, is similar to the Test, Operate, Test, Exit or TOTE model of learning advanced by Miller, Galanter and Pribram (1960). Lewis and Pask (1965) contend further that the conversational model of learning is also congruent with the theories postulated by Piagét and Vygotsky, although an elaboration of the relationships is not provided. Pask (1975) provides further support to the contention that it is cognitive theories of learning that underlie the designs of his machines. While Pask argues against the methods postulated for discovery learning, he states that the idea of discovering connections between new concepts and ones already learned is excellent and it can be shown to work through empirical methods. To test this theory of learning in an empirical manner, Pask and others devised a number of computer-controlled machines that function according to the principles of fuzzy logic and which are also designed from explicit cognitive theories of learning. Most of these experimental machines were not intended to be marketed commercially. While most of the machines constructed during the 1950s and early 1960s were analogue-based machines for reasons of expense and size, some later versions were hybrid machines, containing both analogue and digital circuits. The digital circuits appear to have been used primarily for scoring and tabulation purposes (Pask, 1966).

Some of the experimental machines devised include the *Eucrates* teaching machine, the *Coordinate transfer trainer*, and the *General Comprehension Trainer* (Lewis & Pask, 1965; Pask, 1975). These devices were designed both to instruct a particular cognitive skill or strategy and to measure and evaluate methods of teaching concept acquisition strategies by machine. The general design of these machines is similar. Each presents information to the learner by means of a matrix of lamps that can be illuminated selectively to focus attention onto a particular drawing in a given matrix or to draw attention to a specific pattern in the matrix. By reacting accordingly to the responses of the learner, the machines endeavor to teach the relationships between concepts by altering what is emphasized in the matrix and by providing other visual cues as to whether the strategies used by the learner are either less or more appropriate. In at least one device, if the learner selects or constructs responses in a seemingly random fashion, a panel is illuminated that displays the words, "You are playing" (Pask, 1966, p. 5). After the presentation of this information, the machine provides other visual information to guide the student toward a more appropriate response or strategy.

Although he was probably unaware of it, Pask (1966) was using computer-controlled machines to conduct experiments in analyzing learning and logic following the same principles of LaZerte's envelope test (see Chapter VI). While both researchers were attempting to discover more about learning in human beings, their experimental findings affected the design of subsequent instructional devices that they produced. In LaZerte's case, he concluded that the devices he invented, while being effective, added to the difficulty of the intended task. Pask, however, concluded that a greater knowledge of the learning process could enable him to design more effective teaching machines that would diminish rather than increase the difficulty of the subject matter being presented. In this manner, a knowledge of theories of learning and their relevance to pedagogy were the decisive factors influencing the design and further development of these instructional devices. Although Lewis and Pask (1965) contend that the initial basis for their computer-controlled teaching machines was artificial intelligence theory, it has been shown how an awareness and an analysis of theories of learning modified the design of Pask's machines markedly.

While Pask's computer-controlled adaptive teaching machines have not had as large an impact upon scholastic instruction as Skinnerian teaching machines, it is important to note that the rôle and deployment of computers in schools continues and there is evidence to show that Pask's findings and theories influenced the designs of some computer-controlled instructional devices developed subsequently by educators and other researchers (Stolurow & Davis, 1965).

Experimental commercially-produced devices

IBM teaching machine projects

Although one version of Skinner's teaching machine was developed to the prototype stage in the late 1950s by the electric typewriter division of IBM (see Chapter VI) another division of the company was experimenting with adapting computers to function as instructional devices. While Skinner was not involved directly with the development of a computer-controlled device, it is ironic that the underlying theory of learning embodied in the IBM device was Skinnerian behaviorism. According to Rath, Anderson and Brainerd (1959) the idea of using a computer to control a teaching machine arose from a perceived need of, "studying those psychological variables which are important in the design of teaching machines. Thus, we became interested in the general characteristics of teaching machines as opposed to the development of a particular machine" (p. 117). From this quote, it seems that the IBM team had goals similar to those of Pask. Rath (1967) notes that although this was the initial intent of the investigation team, the Psychology Department of IBM was of the impression that since the executive office was already interested in teaching machines, it might be prudent for other research to be carried out on these lines, "This led to the choosing of a teaching machine simulation instead of the human prediction of Markov chains or the analysis of complex motor responses, both of which had also been under consideration" (p. 60). Instead of theoretical and pedagogical factors, it was the perception of possible corporate policy that determined how computers at IBM would be designed as instructional devices initially.

An IBM model 650 computer was used, a large vacuum tube driven digital unit designed primarily for business purposes and consisting of three discrete units. One cabinet contained the power supply. Another cabinet, the largest of the three units, contained the processor, memory drum and a programming console. The usual method of input and output was by means of a separate combination card reader and punch (Reid-Green, 1979a). As this method of input and output was inappropriate for instructional purposes, an electric typewriter was modified so that it could be connected to the processor. Rath, Anderson and Brainerd (1959) note that although the modified typewriter functioned satisfactorily, an input-output device designed especially for interaction with the computer was considered to be more desirable.

The computer was prepared to instruct one subject only, binary arithmetic. This subject was chosen in part because the programs of many computers of the time were written in binary code. Another reason is because binary arithmetic possesses fewer new concepts to learn than some other areas of mathematics. It appears that binary arithmetic was also selected because of technical limitations of the 650 computer (Rath, Anderson & Brainerd, 1959). Reid-Green (1979a) notes that in spite of its large physical size, the 650 possessed a total memory capacity equivalent approximately to 4 k Bytes. Programs that exceeded this memory capacity cannot be run. The 650 also did not have the capability to drive a visual display.

The operation of the experimental 650 system was similar to a combination of Skinner's Didak teaching machine and Crowder's branching AutoTutor teaching machine (see Chapter VI). By controlling the typewriter, the computer first types a number of instructions, definitions and examples of operations. Next, a question is typed and the user is requested to construct a response using the keyboard. Evaluation of the response begins as soon as the first key is pressed, even though the response may require more than one character. If the character entered is correct, no action is taken by the computer. The user continues to enter any additional characters. If the entire question is entered correctly, the computer proceeds immediately to the next question, disregarding any additional entries made by the user. This arrangement is made to prevent the user from entering additional characters that may be incorrect (Rath, Anderson & Brainerd, 1959).

If the user enters an incorrect character before the entire response is completed, the computer interrupts further input by the user and types "WRONG". Remedial information is then typed by the computer immediately. The level of remedial information depends upon the number of errors made by the user previously. The greater the number of errors, the more extensive the remedial information. After this information has been typed, the user is then required to answer another question that is either at the same level of difficulty of the initial question, or one that is simpler. The computer makes this choice on the basis of the number of errors made in that portion of the program (Rath, Anderson & Brainerd, 1959). Rath (1967) notes that response entry can be confusing to the user in two ways. First, the computer does not permit backspacing, so mistakes cannot be obliterated. Second, the computer moves the position of the print head one space to the right after each entry. This attribute can create a confusing display. In an addition problem requiring the creation of a column of numbers, for example, the carriage return must be pressed after each number is typed. This causes the column to appear along an oblique plane (Rath, 1967).

Although Rath, Anderson and Brainerd tested their computer-controlled system with several students, they report that no experimental results were gathered. The authors also note that the computing capabilities of the model 650 were not being used effectively, since only one student could use the apparatus at a time and the computer could, through multiplexing, operate several terminals (Rath, Anderson & Brainerd, 1959).

A second experimental project using computers as teaching machines was launched by IBM in 1960 (Uttal, 1962). A model 650 computer was used again, this example being a unit salvaged from other applications (Rath, 1967). Several modifications were made to the 650 in this study. Through the addition of multiplexing circuitry, up to 20 computer-controlled typewriters could be connected (Uttal, 1962). Rath (1967) reports that only 6 terminals were connected. Instructional materials were prepared for three subjects, stenotyping, psychological statistics and German reading. While the typewriters were satisfactory for instruction in statistics and German reading, a special keyboard was required for stenotyping. As well as designing a computer-controlled stenotype keyboard, a screen was also provided that could display: alphabetic characters by means of nixie tubes; the images of a 1000 slide capacity random access projector; and cue lights corresponding to the keys of the keyboard (Uttal, 1962; Rath, 1967).

While the operation of the system for the subjects of psychological statistics and German reading was similar to that of mechanical teaching machines described in the previous chapter, the operation of the system for teaching stenotyping was similar to Pask's adaptive keyboard machines. A particular word or letter is displayed on the screen and the user prompted to press the correct key within a given interval. Mistakes or the excessive passage of time causes the computer to illuminate one or more of the cue lights. In this manner the computer provides feedback and guidance to the user.

While the two IBM projects establish that a computer can function as a teaching machine, several limitations were revealed. First, it became apparent that computers designed primarily for business applications could not be modified easily for instructional purposes, because of the need of specialized input and output devices (peripherals). Second, large computers, although they can operate several terminals through multiplexing, were likely too expensive for most schools. Third, while programs of instruction could be written for computers of that time, the individuals who performed the programming usually possessed specialized knowledge of computer languages and programming techniques, skills not usually possessed by educators. While IBM developed a commercial instructional system eventually that addressed the limitations just mentioned (Rath, 1967) other concerns had already designed experimental systems that employed smaller computers capable of operating a number of terminals simultaneously and which could be programmed by individuals not possessing extensive programming skills.

CLASS

Like IBM, the System Development Corporation of California was intrigued by the popularity and the apparent efficacy of Skinnerian-based teaching machines. Rath (1967) contends that the company's interest in teaching machines arose primarily from their work with the United States Air Force. By 1958, System Development was interested in exploring the possibilities of a computer-controlled teaching machine (Coulson & Silberman, 1959b). While Coulson and Silberman (1959b) note that Skinner likened his teaching machines to private tutors, the authors also state that a, "good tutor, however, makes use of a high degree of flexibility that does not exist in Skinner's machines" (p. 8). It is noted further that while branching-type teaching machines introduce some degree of flexibility in the interaction between man and machine, the flexibility is insufficient to result in learning that is significantly superior to less flexible linear-type teaching machines.

Coulson and Silberman (1959b) contended that "some type of automatic equipment" a computer specifically, would provide the flexibility hitherto lacking in teaching machines (p. 7). While several computer models were considered, large units such as those produced by IBM were deemed to be too expensive to modify for instructional use (Coulson & Silberman, 1959b). A smaller digital computer, a Bendix model G-15, was selected ultimately (Coulson, 1960). While it had a smaller memory capacity than the IBM 650, the G-15 was less expensive and it could be adapted more easily to instructional purposes. Part of the flexibility of the G-15 came from its ability to be programmed by means of punched paper tapes (Coulson, 1960). Like the IBM 650 project, interaction with the student was through an electric typewriter connected to the computer. Additional information was presented by a specially designed random access slide projector, also under the control of the computer.

While cathode-ray tubes had been used as storage devices in some computers beginning in the 1940s (Augarten, 1984) it appears that most computers constructed before the 1960s lacked the capabilities required to drive a raster-type cathode-ray tube (CRT) display. Reid-Green (1979b) reports that early attempts at producing a dynamic raster display resulted in considerable image flicker because of the relatively slow clock speeds of computers at that time. The use of a slide projector with the G-15 was intended to enable the computer to present iconic information to the user, something not accomplished easily using an electric typewriter. Coulson (1960) reports that the projection system could display up to 600 different images stored as 35 mm slides, and that the maximum search time was about 7 seconds. Foltz (1961) reports that this instructional configuration was referred to as *UNCOL*. This designation is likely incorrect, since works written by authors who worked with the apparatus do not mention the name. Also, Sammet (1969) indicates that UNCOL refers to a proposed computer language called *UN*iversal *C*omputer *O*riented *L*anguage that was not developed past the design stage.

The operation of System Development Company's experimental computer-based instructional device is similar to that of Crowder's AutoTutor teaching machines. By pressing a key, the user informs the G-15 computer that he/she is ready to begin the lesson. The computer then selects a particular slide and projects it on a screen in front of the user. The slide contains information, illustrations if necessary, and a multiple-choice question. The user then enters a response by pressing the appropriate key on the electric typewriter. If the delay between the presentation of the slide and the response is deemed too long by the computer, it causes a bell to ring until a response is entered (Foltz, 1961). Coulson (1960) states that the bell serves as a means of providing, "programmed auditory signals" (p. 1). This method appears to be a means of negative reinforcement, where a noxious stimulus is presented until the desired behavior is emitted by the subject. The ultimate goal of this method is to condition the subject to respond before the noxious stimulus is presented.

If the entered response is correct, the computer will type a message indicating that fact and a new slide will then be presented. An incorrect response results in the computer typing a message indicating that the response is incorrect. Slides of remedial information are then presented by the computer (Coulson, 1960). Silberman and Carter (1965) report that a major disadvantage to this instructional system is that only one terminal can be operated at a time. To take advantage of the potential computing power available, a different configuration was devised by 1961 (Coulson, 1962).

Referred to as *CLASS*, an acronym for *C*omputerized *L*aboratory for *A*utomated *S*chool *S*ystems, the apparatus was designed for the individualized instruction of large groups. Its principle of operation is similar to some feedback classroom-type teaching machines described in Chapter VI. Up to 20 special terminals could be connected and operated simultaneously by the computer. Instead of using typewriters for user input, response units each containing five response keys and a key labeled *enter*, were connected to the computer (Foltz, 1961). The purpose of the *enter* key is to permit users to alter their selections before having them evaluated by the computer. The computer remains unaware of any key presses until the *enter* key is pressed, a feature not present in the initial experimental system. Three push-buttons are also located on the response unit. These are used as special signals to gain the attention of the computer or the assistance of a human being (Coulson, 1962). Besides being less expensive than electric typewriters, the simplified keyboards limit the number of keys that the user attends to. In this way it may be contended that the CLASS response unit adds a minimum amount of difficulty to the intended task.

Coulson (1962) notes that each response unit was also equipped with a four character digital display, likely produced by nixie tubes, and several coloured lights, all under computer control. The digital display provides the user with simple instructions such as page or frame numbers for accompanying materials, while the coloured lights provide visual feedback on whether a response is correct or incorrect (Coulson, 1962). Prompting lamps located next to each response key permit the computer to indicate the correct response on the response unit. Most of the instructional material and questions in CLASS are presented either on a separate filmstrip projection unit located adjacent to the response unit, or by book. The computer does not control the projection unit. Instead, the user moves the filmstrip manually by means of a crank located on the right-hand side of the unit (Coulson, 1966). This capability enables the user to review material at will. Figure 81 (after photograph in Silberman & Carter, 1965, p. 76) shows the general appearance of a terminal used in the CLASS computer system.

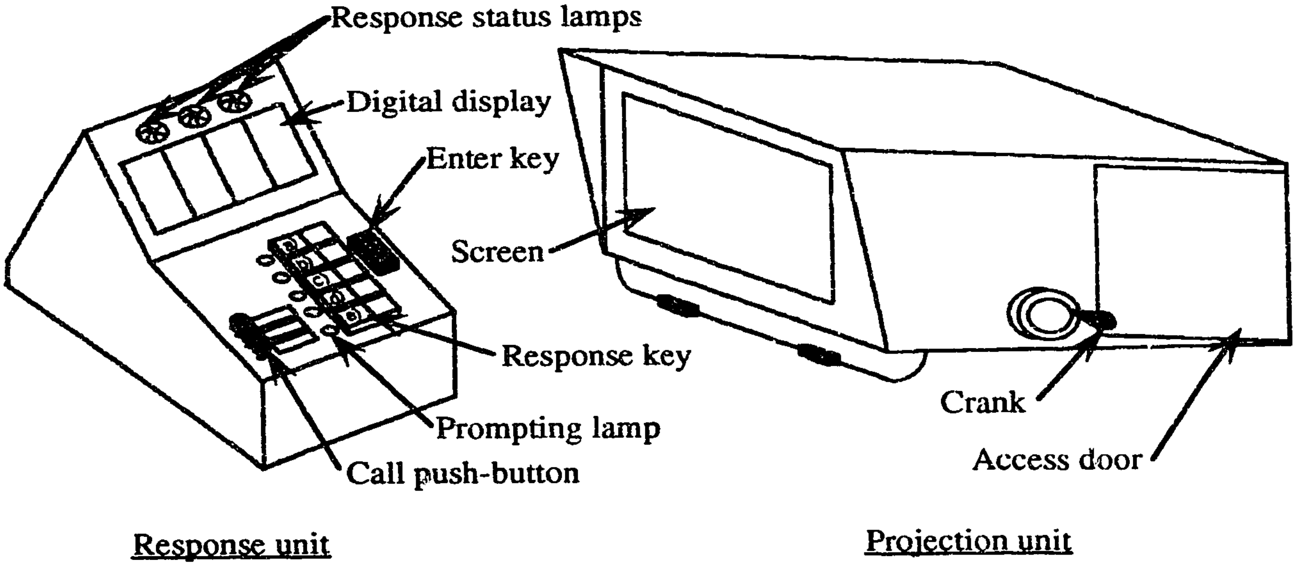


Figure 81. General appearance of a CLASS terminal

A tape recorder with headphones could also comprise a part of each terminal. Like the projection unit, the tape recorder was under the manual control of the user. Coulson (1966) notes that the tape recorder was especially useful when the CLASS was used for language instruction and when lessons were presented to young children.

A time-sharing system was developed to enable the computer to communicate with and to control each terminal independently. Coulson (1966) states, "Although the computer actually worked with a single student at a time, it could process information so rapidly and move from one student to another so quickly that no student experienced any distracting delays" (p. 5). Silberman and Carter (1965) state that it is the advent of such time-sharing systems that enabled the cost of computer-controlled instructional systems of this variety to be reduced so that they were more affordable to schools. A computer with a larger processing and memory capacity than the Bendix G-15 was required to accommodate the time-sharing system. Coulson (1966) reports that a Philco model 2000 computer was used.

An experimental classroom laboratory resembling a language laboratory was constructed by System Development Corporation to test the CLASS system. Silberman and Carter (1965) justify the experimental laboratory by noting two apparent factors within most educational systems that affect the general development and deployment of innovations negatively. First, the authors note the apparent lack of desire within existing educational institutions to pursue experimental programs that are not guaranteed to be deemed successful. Silberman and Carter (1965) state, "There are no truly experimental laboratory schools. University laboratory schools tend too often to become genteel demonstration schools for the benefit of faculty children… making only modest nods toward experimentation" (p. 73). While the authors recognize that some educational research into the effectiveness of instructional devices is undertaken, they maintain that simply publishing results and criticisms is not enough, since no link is usually made between the theoretical and practical. To be effective, therefore, Silberman and Carter (1965) contend that research must involve actual devices and provide a practical basis for change or modification of existing apparatus. Moreover, the authors maintain that experiments with instructional devices cannot be delegated or left to commercial enterprises. Silberman and Carter (1965) state, "We cannot expect the commercial publishers of educational material to produce empirically-developed instructional materials since they work in a very competitive environment and their retail price must absorb all developmental expenses" (p. 74). It may be asked in view of this quote, why the System Development Company was interested in testing and developing instructional devices. Coulson (1966) notes that while the System Development Company is primarily involved with contracts for the military, it was created from the Rand Corporation in 1957 as a non-profit organization. Accordingly, Coulson (1966) states that the company maintains a policy of allocating some "income in excess of direct operating costs" to other research projects, "that is, noncontractual research that contributes to the public welfare" (p. 1). In view of this policy it may be contended that the System Development Company could engage in such research objectively because it had no ostensible profit-motive for conducting such research and development.

The second condition the authors note that affects innovations and instructional devices negatively, is that they are introduced prematurely because educators are too easily influenced by the effects of widespread publicity. The effect of deploying instructional devices because of such public attention is that it becomes practically impossible to evaluate the device objectively, or in some instances, it is believed that evaluations of it may be dispensed with altogether (Silberman & Carter, 1965). Silberman and Carter (1965) propose a solution by stating that the impetus for innovation and development should be centred at the national level rather than at the commercial level. By providing a government-run experimental laboratory, new instructional devices would be tested and evaluated without causing turmoil and unnecessary hardship within individual schools. Silberman and Carter (1965) maintain that with this approach, "There would be a shift from an unsolicited to a solicited and from an individual to a programmatic research policy" (p. 89). While the authors state that initial funding would have to be provided by the federal government, the success of the laboratory would be such that it would become self-sustaining. Licensing arrangements would help ensure that publishers and other private developers would not consider their markets threatened (Silberman & Carter, 1965). Coulson (1966) who also worked with the System Development Company did not agree with this proposal. Coulson (1966) states, "that the local schools should take the initiative in forming such cooperative efforts, rather than waiting for the federal government to assume the lead" (p. 10). While the federal governments of both the United States and Canada have made some attempt at providing leadership in the development of educational innovations, neither government has embarked on a program with the magnitude proposed by Silberman and Carter (1965).

Although the computer-controlled instructional devices developed by the System Development Company did function as expected in experiments, neither was marketed commercially. The cost of the apparatus was likely considered to be still too high for most schools, in spite of using smaller and less expensive equipment. Coulson (1966) states, "The costs of data-processing equipment are expected to drop drastically within the next 10 years, but such equipment will nevertheless require a large initial expenditure and long-term financing commitments that may be extremely difficult for many schools to manage" (p. 9).

On the basis of their research using the CLASS, Silberman and Carter (1965) discovered another factor that impinges negatively on the appropriateness of computers as instructional devices, a factor noted in Chapter VI in respect to teaching machines. Silberman and Carter (1965) state,

> One of the first things that became apparent in this research was that the potential advantage of the machine [computer] was limited by the quality of the instructional material... it is a comparatively simple mechanical task to branch a student who is having trouble to remedial material. But it is quite another thing to design remedial sections that will rectify his difficulty once he is branched to that material. (p. 76)

The experiments conducted by Silberman and Carter (1965) reveal that although consideration was given to cybernetic theory and to equipment design, simply accepting a theory of learning as appropriate, Skinnerian behaviorism in this case, is insufficient to ensure efficacy of the device in use. An evaluation of the efficacy of the pedagogical method selected is as essential an element as the theoretical design of the apparatus and the theory of learning invoked. In spite of these findings, some private and commercial designers of computer-controlled instructional devices continue to ignore them.

Tacden machine

It is noted in Chapter VI that through interest and financial support, the United States military was in large part responsible for the rapid growth of the teaching machine industry in North America. The same claim may be made in respect to the development and the proliferation of computer-controlled instructional devices. It is noted previously that much of Pask's funding came from military sources and, in consequence, many of the machines he designed were intended for military applications. Other early developments of computer-controlled instructional devices were also funded by the military. One example is the *Tacden* teaching system constructed by the Aeronutronics division of Ford Aerospace Communications Company. Finn and Perrin (1962) indicate the name as *Tachden*, however. Construction of the device was undertaken for the United States Army Signal Corps Research and Development laboratory at Fort Monmouth, New Jersey, beginning in 1958 (Correspondence with Aeronutronics division of Ford Aerospace Communications Company, February 4, 1988). The Tacden system was controlled by a digital computer and each terminal possessed a small CRT by which information and questions were presented to the user. From the early date of its development, it appears that the Tacden system represents one of the first uses of a computer-driven CRT to present information to the user. It is likely, given the small size of the display, that it was capable of generating images of low resolution and that it was used primarily to present textual information and questions rather than graphic information. User response was by means of a typewriter-like keyboard located on the terminal (Finn & Perrin, 1962). It is not known, because of unavailability of relevant documents from the United States Army, what type of computer controlled the terminals, how many terminals could be operated at once by the computer, the subject matter presented by this system, or the instructional theories and pedagogical methods used by this system. It is known that the Tacden project was discontinued in 1964 (Correspondence with Aeronutronics division of Ford Aerospace Communications Company, February 4, 1988) so it is likely that the project was experimental and was not expanded and modified for civilian use.

Commercially-produced computer-controlled devices

TRW Mentor

While the experimental machines of the System Development Company demonstrated some of the capabilities of using a single digital computers to control several instructional terminals, some companies attempted to market computer-controlled instructional devices by relying on smaller and less complex apparatus that was usually less expensive. In spite of the comments made by Silberman and Carter (1965) admonishing the development of instructional devices by commercial enterprises, there is evidence to show that several companies were engaged in the production and the development of computer-controlled systems even though the cost of such systems was likely too high for most educational institutions.

One example of this phenomenon is the device called the *TRW Mentor* (Chapman & Carpenter, 1962) manufactured by the Intellectronics Division of Thompson, Ramo, Wooldridge Incorporated (known as TRW since 1965). The TRW Mentor, introduced by 1961, is similar in basic construction to some of the machines designed by Pask, since it employs a self-contained analogue computer that operates only one terminal at a time (Foltz, 1961; Finn & Perrin, 1962). Romaniuk (1970) reports that while the Mentor was designed to be an instructional system, it was adapted from an existing commercial system designed for data processing. The apparatus comprising the Mentor is contained in a housing that also doubles as a desk for the user. Unlike Pask's machines, the TRW Mentor may be programmed to provide instruction in different subject matters. Figure 82 (after photographs in Chapman & Carpenter, 1962, p. 245; Finn & Perrin, 1962, p. 46) shows the external appearance of a TRW Mentor machine.

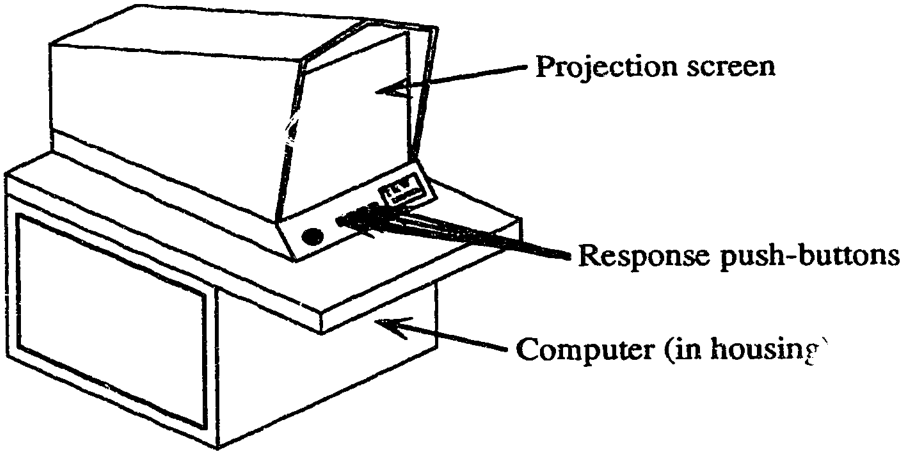


Figure 82. General appearance of a TRW Mentor computer-controlled instructional device

The operation of the Mentor is similar both to the first experimental System Development Company device and to the Crowder-designed AutoTutor teaching machines (Foltz, 1961). The analogue computer, besides controlling the progress of the program, also controls a random-access 16 mm filmstrip containing up to 17,000 frames of colour film or up to 25,000 frames of black and white film (Chapman & Carpenter, 1962). The computer also controls a synchronized 4-track tape recording (Finn & Perrin, 1962). The TRW Mentor presents information and questions to the user by means of projected still or moving images and through recorded sound. The user responds to questions by means of four push-buttons (Chapman & Carpenter, 1962). The computer evaluates the response and then presents either the next image in the series, skips the user ahead to more challenging material, an amount of remedial information, or a test. While it functions in a manner similar to Crowder's AutoTutor teaching machines, the computing capability of the TRW Mentor permits a much more versatile programming approach, since the programmer is not restricted to a particular pattern of either a linear or a branching program (Chapman & Carpenter, 1962).

Factors affecting deployment

While Pask demonstrated that instructional devices need not follow the principles of programmed instruction, many individuals involved with developing teaching machines and programs for them did not consider any approach other than those developed for teaching machines. Many of these individuals considered computers as little more than a more efficient teaching machine. Foltz (1961) provides support for this contention,

> At present much of the programing being done is limited by the mechanical deficiencies of devices to present these materials... computer-centered devices, with their capacity for programing tailored to the student's own personal needs... would be by far the best devices to implement the socratic method... Until a reasonably economical method can be found to design, build and program such devices, we must be satisfied with half-way measures (pp. 51-52).

Instead of considering how the capabilities of computers might be used to create new and perhaps more effective methods of instruction, Foltz (1961) reflects the view that the methods of programmed instruction are already perfected, limited only by the machines used to present the material. He implies, moreover, that the major criteria for selecting instructional devices are their ability to be adapted to present programmed instruction and their cost. While the TRW Mentor was capable of more versatility than most electromechanical teaching machines of the time, it was still designed largely for the presentation of programs following variations of either the linear or branching models.

Cost appears to be another major factor that affected the deployment of the TRW Mentor negatively. While Foltz (1961) reports that the anticipated American price of the Mentor was between $5,000.00 and $7,000.00, it is not known how many units were sold and what instructional materials were available for them. It is likely, however, that demand was lower than expected because of cost. Chapman and Carpenter (1962) contend that simply considering the unit cost of such computer-controlled instructional devices is misleading, "We need to be concerned with relative, rather than absolute, costs. The relative cost compares the value of the results with the expense of obtaining them" (p. 252). Rath (1967) reports that TRW did not sustain interest in developing computer-controlled instructional devices and/or systems.

BBN Mentor

In 1959, Bolt Beranek and Newman Incorporated (BBN) began experiments investigating the applicability of computers to instruction (Rath, 1967). Instead of designing their own computer or modifying one designed for some other purpose, BBN used general purpose digital computers. The first unit obtained was a Royal Precision model LGP-30, thought to be suited for being programmed to function as a teaching machine (Rath, 1967). Licklider (1962) notes that some initial experiments were conducted using this computer. While performing scoring and selecting tasks, which could entail time intervals noticeable to the user, the computer could not present feedback, nor could it process any input. To dissuade the user from concluding that the computer was not responding, the apparatus was configured so that during processing tasks the output device, a typewriter, would perform spurious activities such as carriage shifts and ribbon movements (Licklider, 1962). The delay in providing feedback was considered excessive, so a faster computer was selected. Manufactured by the Digital Equipment Corporation (DEC) and configured for the experimental instructional system designed by BBN, the general model is designated as *PDP-1*, the three letters standing for *Programmed Data Processor* (Licklider, 1962). Foltz (1961) reports that the computer, as modified for instructional purposes, is referred to as a PDP-1B.

The selection of the computer appears to have been influenced by the learning theories ascribed to by the designers at BBN. The designers, in turn, may also have been influenced by the interest in Skinnerian behaviorism shown by the American military, since Rath (1967) reports that BBN was interested in obtaining contracts from the United States Air Force. There is evidence to show that Skinnerian behaviorism comprised the major theory of learning underlying the design of BBN's system. For example, Licklider (1962) states, "there is little doubt that accumulation of facts and elementary behavioral capabilities are prerequisite to advances at conceptual and integrative levels" (p. 218). Licklider (1962) contends further that immediate feedback and reinforcement are also essential elements in learning. As well as speed of processing, the PDP-1B could also drive a CRT display to present feedback. This feature, from a behavioristic position, is considered superior to using a typewriter, since it takes less time to generate a line of text on a CRT than it takes a typewriter to type the line. Licklider (1962) states, "The student still answers via the typewriter, which limits the pace, but the display of stimulus items and reinforcers is almost instantaneous" (p. 228).

Two typewriters, a CRT display and a *light pen* comprise the main input and output peripherals for users (Licklider, 1962). A light pen or a *light pencil* as it is sometimes referred to (Rath, 1967) is a specialized input peripheral that consists usually of a hollow metal or plastic cylinder containing either a photodiode or fibre optic cables which are connected to a photomultiplier tube located usually inside the display housing (Hlady, 1968). To activate the light pen, the user either closes a switch on the pen housing, or the light pen is pressed against the screen of a CRT, and this pressure closes a switch which activates the photocell. The light pen reacts to the flash of light at that point, produced by the electron beam as strikes the phosphors of the screen. Decoding circuits within the computer enable it to ascertain the position of the light pen on the screen (Chandor, Graham & Williamson, 1977). By using a light pen, the user may indicate to the computer a particular location or a series of points on the screen, provided that pixels are illuminated in those areas. It is possible, therefore, for the user to enter a drawing (Hunka & Romaniuk, 1974). While a device similar to the light pen had been used in the Whirlwind project in the 1950s (Everett, 1980) it seems that BBN's use of the light pen represents one of the first uses of this type of input peripheral for instructional purposes. Rath (1967) reports that knowledge of the light pen likely came from BBN's work with the United States Air Force, who used light pens for other purposes.

Licklider (1962) reports that for BBN's system, the light pen was intended to enable the user to enter a curve from which the computer generates a parabola on the screen. Additional peripheral devices of the system were intended primarily for the use of programmers. These devices included a card reader, two paper tape-punch machines, an analogue to digital converter, two digital to analogue converters, and 16 relays (Licklider, 1962). Rath (1967) notes that the converters were used to enable the digitization and the subsequent re-creation of sounds. A program was devised to teach discrimination between particular sounds, primarily those sounds associated with sonar detection. A series of sounds is presented by the computer to the user. The user is then presented with a single sound and he/she indicates to the computer which position in the original sequence that sound occurred. Once a selection is made, the computer reproduces that sound and then the correct sound if an incorrect selection was made (Rath, 1967). Licklider (1962) states that BBN's experiments with computer-controlled instructional devices reveal that hardware engineering is as important as the learning theory selected, since the ultimate configuration of hardware used resulted in, "increasing performance by 50%" over earlier configurations (p. 228). This finding refutes the claims made by Skinner and others in respect to teaching machines, that learning theory is the sole predominant factor in determining the success of a pedagogical method.

As well as innovative uses of peripheral devices, BBN also designed a special type of programming language for its Mentor system. Referred to also as *Mentor*, the language can be considered an *authoring* language, since it permits the programmer to enter commands using English words according to a pre-determined instructional format. Additional software running on the computer compile and interpret the Mentor language into binary code that is understandable by the machine (Romaniuk, 1970). In this way the computer may be programmed by individuals who may possess expertise with content, but who are largely ignorant of the intricacies of computer programming using traditional programming languages. This feature is important since authoring languages attempt to diminish the gap between computer programmers and educators or content experts. Additional information about computer languages will be provided in subsequent sections.

Although Licklider (1962) reports that BBN's experiments with instruction provided by computer were successful, he states that such systems were not yet developed to the point where they could be deployed in schools generally, "The economic feasibility of widespread exploitation of computer-aided teaching in large schools, school systems, government, and industry depends upon the development of time-sharing computer systems and rugged, flexible, inexpensive input-output equipment for student stations" (p. 239). It is evident from this quote, that economic and hardware engineering factors were considered, in some quarters, to outweigh the importance of what theory of learning was used.

Message composer

One system, believed to be designed for commercial applications primarily, was a device called the *Message Composer*, manufactured by the Marquardt Corporation (Finn & Perrin, 1962). Although there is little information available about this system, it is known to consist of a terminal containing both a small cathode-ray tube and a typewriter-like keyboard. Finn and Perrin (1962) report that the device can operate from "an internal format", or it can be controlled by connecting it to a digital computer (p. 47). The type of digital computer required or the instructional designs incorporated in the machine are not mentioned. It is possible, given the limited information discovered about this device, that its production was either extremely limited or non-existent.

Computer-controlled devices and systems designed through collaborative efforts

PLATO

Although the development of some of the first computer-controlled instructional devices and systems was undertaken by commercial concerns, much development that led ultimately to the use of such devices in schools occurred as combined effort between academics and corporations. It is noted in Chapter VI that by the late 1950s educators in general and many academics specifically were interested in the use of teaching machines and instructional devices. At the same time, computers were gaining prominence as efficient devices in other areas such as computation and particular business applications. Individuals such as Pask and corporations like IBM had also created a link between computers and instruction. At that time, however, Pask as well as many individuals within the various corporations mentioned previously, possessed limited knowledge both of theories of learning and of methods of pedagogy likely to succeed in a variety of educational settings. Interest in instructional devices by academics and the perception that developments by computer programmers and computing engineers, likely led some educational institutions to conclude that more appropriate applications in education might be made by combining these disparate elements of expertise with individuals possessing extensive knowledge of learning and pedagogical theory. Rath (1967) indicates that this condition existed at the University of Illinois by 1960. At that time, a committee of between 20 and 30 individuals was struck to ascertain the possibilities of designing a viable computer-controlled instructional system containing elements from education, psychology, and computing engineering. Rath (1967) reports, "This committee concluded that nothing could be done or should be done about using computers to teach because of the wide disagreement between its members" (p. 63). Before abandoning the proposed project altogether, the committee report was shown to two interested individuals who were given two days to prepare comments. The individuals were Donald Bitzer, an electrical engineer and Peter Braunfeld, a mathematician and computer programmer (Bitzer, Braunfeld & Lichtenberger, 1961). They disagreed with the findings of the committee and instead proposed an instructional system that would at first use the home-made computer of the University of Illinois (Rath, 1967).

The instructional system was called PLATO, an acronym for *P*rogrammed *L*ogic for *A*utomatic *T*eaching *O*perations (Bitzer, Braunfeld, & Lichtenberger, 1961). The initial configuration, called PLATO I, was operational by the summer of 1960 (Rath, 1967). The first version of the University of Illinois' general purpose, vacuum tube based, medium-speed computer called ILLIAC I, comprised the main component of the PLATO I system (Bitzer, Hicks, Johnson & Lyman, 1967). Augarten (1984) notes that ILLIAC is an acronym for *ILLInois Automatic Computer.* The configuration could operate only one terminal. Input to the ILLIAC from the user was by means of a special panel containing 16 keys. Output to the user was by a small CRT television-type display (Bitzer, Braunfeld, & Lichtenberger, 1961).

Two separate sources were available for generating images on the television screen. One video source referred to as an *electronic book* consists of an array of 61, 35 mm slides, arranged in a hexagonal pattern. Through electronic means, the image of a given slide could be displayed. This was accomplished by placing each slide on top of a photomultiplier tube and by locating a collimating lens array above the slides. The beam of a single 5 inch (127 mm) flying-spot scanner CRT was then used to scan each slide, the beam of light produced by the scanner being focused on each slide by the lens located above it (Bitzer, Braunfeld, & Lichtenberger, 1962; Handel, 1971). The collimating lenses reduce the raster pattern produced by the flying-spot scanner, so that each micro-image is scanned. The resulting scanned image is projected onto the corresponding photomultiplier tube. The video images resulting from this procedure were amplified and then transmitted by cables to the ILLIAC. The computer determined not only which photomultiplier tube would be connected to the display terminal, but when it would be connected and for what duration. The time required to access a particular image, approximately one millisecond, was fast in comparison to computer-controlled projection systems using electro-mechanical slide selectors such as that used by the System Development Company.

The second video source was known as an *electronic blackboard* (Bitzer, Braunfeld, & Lichtenberger, 1962). This apparatus consisted of a Williams cathode-ray storage tube onto which the ILLIAC could generate images such as drawings, special characters and graphs. A scanner was used to transfer the information displayed on the storage tube to the user's CRT display (Bitzer, Braunfeld, & Lichtenberger, 1962). The video output from the storage tube could be mixed with the output from the photomultiplier tubes. In this way images from both sources could be combined. The reason for presenting information from both sources is to enable the system to display material constructed by the user in conjunction with fixed materials on the slides. Bitzer, Braunfeld, and Lichtenberger (1962) state, "when a question is asked on a slide, the electronic blackboard makes it possible for the machine to display the student's answer superimposed on the slide in an appropriate place" (p. 209). In this fashion, PLATO could function at a more sophisticated level than almost all of the electro-mechanical teaching machines of the time.

Although PLATO was designed initially to function according to the principles of programmed instruction (Bitzer, Braunfeld, and Lichtenberger, 1962) the flexibility of operation provided by computer enabled PLATO to possess greater flexibility than even the most elaborate of the branching-type teaching machines (see Chapter VI). In a manner similar to teaching machines, PLATO presents information to the user initially. If more than one slide is required, then the user presses a key labeled *continue* when he/she is ready to proceed. Another key, labeled *reverse*, enables the user to review information presented previously. When a question is presented, the user constructs a response using the keyset. If the question requires arithmetic calculations, the user presses the *calculate* key. This action causes a small frame to appear on the screen and also causes the computer to function as a calculator. Calculations are performed by entering numbers and pressing the desired operand keys (Bitzer, Braunfeld, & Lichtenberger, 1961). Evaluation of the response by the computer does not occur until a key labeled *judge* is pressed. At this juncture, by using subroutines in its program, the computer evaluates the response and prints either *OK* or *NO* next to the response (Bitzer, Braunfeld, & Lichtenberger, 1961). If the response is deemed correct, then the user is permitted to proceed.

Several choices are available when a response is judged incorrect. The user may revise the response and have it judged again, or the *help* key may be pressed. Pressing this key causes the computer to present a number of slides containing supplementary information which ends with a slide presenting a sub-problem or question. If the user realizes what the response should be while the supplementary information is being presented, the sequence may be interrupted by the user pressing a key labeled *aha* (Bitzer, Braunfeld, & Lichtenberger, 1961). The user is then returned to the last question before the *help* key was pressed. This feature eliminates much of the boredom and frustration that might be experienced by a user who is obliged to proceed through the entire remedial sequence when he/she has realized what the desired response is. If, after pressing the *aha* key, the response entered is also incorrect, the *help* key may be pressed again, and the user will be returned to the position in the help sequence when the *aha* key was pressed. If the user is unable to construct the correct response after the entire help sequence is presented, the *help* key is pressed again and this causes the computer to provide the correct response (Bitzer, Braunfeld, & Lichtenberger, 1961). Like several teaching machines, PLATO records the actions of the user and is able to present the data when requested by an instructor or an operator.

While presenting the correct response may assist some users to learn the material, others might use this feature as a way of avoiding work. Bitzer, Braunfeld, and Lichtenberger (1962) report that presenting the correct response when the *help* key is pressed twice was dictated by memory limitations of the ILLIAC. In spite of this limitation to the system, PLATO was considered a success. Bitzer, Braunfeld, and Lichtenberger (1961) note that in trials, a half-hour demonstration of how to interact with the machine was sufficient to enable individuals to use PLATO without major difficulties. This observation is significant, since it suggests that the task of learning to interact individual progress through a lesson, but it also provides the user with a number of choices concerning the extent of assistance and remediation. While some teaching machines, such as those designed by Crowder, attempt to provide such flexibility, most are limited by the electro-mechanical technology prevalent at the time. By the same token, the first version of PLATO was also constrained, since it was capable of operating only one terminal at a time. It is noted previously that Rath, Anderson and Brainerd (1959) had already recognized that the computing power of most computer-controlled instructional systems was not being exploited when only one terminal was operated. This observation was likely considered by those concerned with PLATO, since a second experimental version of the system was operational by the beginning of 1961 (Lyman, 1978).

The second version of PLATO, controlled initially by the ILLIAC, was capable of operating two separate terminals (Bitzer, Braunfeld, & Lichtenberger, 1962). While the basic configuration of PLATO II was similar to PLATO I, there were some differences. The keysets of PLATO II contained all of the alpha-numeric keys as well as the special function keys described previously. Other differences between the two versions consisted of hardware additions and modifications that were not readily noticeable to users. The ability of the ILLIAC to drive two terminals was dependent upon multiplexing circuitry. With this system, it was possible for each terminal to be located at remote sites away from the ILLIAC, the distance from the computer being limited by the strength of the communicating signal between the terminal and the ILLIAC. Lyman (1978) reports that the first test of a remote terminal occurred in March 1961, with a terminal located 30 miles (48.2 km) from the ILLIAC.

The difficulty of time-sharing via multiplexing circuitry was compounded by the memory limitations of the ILLIAC, a Random Access Memory (RAM) capacity of 1024, 40 bits, and a memory drum storage capacity of 25 k Bytes, 40 bits. This limitation imposed by technology raised a pedagogical concern. Bitzer, Braunfeld, and Lichtenberger (1962) state, "Students tend to become confused if the computer does not respond immediately to their commands... Care must be taken, therefore, to avoid situations in which the computer is tied up for long periods" (p. 214). To alleviate this problem, some of the control circuitry was located in each terminal, so that some of the more common commands, such as erasing the *electronic blackboard* were performed by local circuitry rather than requiring the attention of the ILLIAC. An additional safeguard against a student encountering no reaction from the computer was to limit the duration that the ILLIAC could attend to one terminal before switching to the other. Bitzer, Braunfeld, and Lichtenberger (1962) report that the maximum duration was ascertained to be 100 milliseconds. With this duration, only two output functions, erasing a storage tube and the plotting of both new and old information on the storage tube required more than one time interval. During times that these functions occur, the only affect to the user is that his/her keyset is deactivated for the duration of the function (Bitzer, Braunfeld, & Lichtenberger, 1962).

In spite of the improvements inherent in PLATO II, the flexibility of the system continued to be constrained by technological factors. Bitzer, Braunfeld, and Lichtenberger (1962) note that the memory capacity of the ILLIAC not only continued to limit the extent of the help sequences, but it also precluded the connection of more than two terminals. The multiplexing capabilities of computer control could not be exploited fully, therefore. This limitation was a major factor contributing to the transfer of PLATO II from the ILLIAC to a Control Data Corporation (CDC) model 1604 digital computer in January 1963 (Lyman, 1978). While the basic configuration of PLATO II remained unchanged when operated by the CDC 1604 computer, a new version of PLATO was designed to take advantage of the increased memory capacity of the CDC 1604 in several ways.

The initial configuration of PLATO III was similar to PLATO II except that the third version could operate up to 32 terminals (Lyman 1978). It seems that only 20 terminals were connected to PLATO III (Bitzer, Hicks, Johnson & Lyman, 1967). The increased memory capacity of PLATO III enabled the system to be modified to permit user entry of simple drawings. To accomplish this, 8 keys on the keyset were modified to function as arrow keys which would move a bright spot or *cursor* on the screen in vertical, horizontal and diagonal directions. (Bitzer & Skaperdas, 1971). When a drawing was required, the cursor and a grid composed of illuminated pixels would appear on the CRT. To draw a line or a polygon, the user first positions the cursor at a desired point and then presses a function key labeled *mark*. The user then moves the cursor to the next desired point and presses the *mark* key again. These points represent vertices of the figure to be drawn. Once the selection of vertices is complete, the user presses a key labeled *close*. At this juncture, a line or lines are drawn between the vertices. If the figure drawn matches the user's expectations, then the *judge* key is pressed to cause the computer to evaluate the drawing (Bitzer & Skaperdas, 1971). The flexibility of the system was enhanced further by 1964, when provision was made to enable inter-communication between terminals (Lyman, 1978). With this feature, PLATO could permit group work or collaborative efforts between students. This pedagogical strategy and capability exceeds that of the electro-mechanical teaching machines including the so-called *feedback classrooms* (see Chapter VI). PLATO III also addressed other limitations to the efficacy and the ease-of-use noted in earlier versions of the system.

Braunfeld and Fosdick (1962) note that the preparation and development of PLATO lessons is constrained by two major factors, hardware limitations and the general philosophy of learning inherent in PLATO. While it has been shown that improvements to the system hardware were being made with each new version of PLATO, the generally complex nature of each system precluded most individuals from programming PLATO lessons. To program PLATO before 1965, it was necessary to possess a knowledge of computer programming, the logical sequence of the lesson, and knowledge of the machine language of the particular computer used (Lyman, 1978). This constraint was of concern to Bitzer (1976) who contends that the PLATO system, "should allow teachers of lesson material to function as authors of the material without becoming computer experts" (p. 244). To enable such individuals to program lessons, modifications were made to both the hardware and the software of PLATO III.

Realizing that there are more than one or two ways to provide instruction using computers, several teaching strategies or *teaching logic* were devised for use by programmers. Bitzer, Hicks, Johnson and Lyman (1967) state that, "Over twenty different sets of teaching rules (logics) have been written for the PLATO system thus far" (p. 64). The authors identify two teaching logics that are used predominantly, *tutorial* and *inquiry*. The earliest available logic, tutorial, was the only one available for PLATO I and it is described in a previous section. Inquiry logic presents a number of problems requiring a variety of problem-solving strategies. The user is able to access reference materials to assist in the selection of a strategy (Bitzer, Hicks, Johnson & Lyman, 1967). In a manner similar to that used in LaZerte's envelope test, the user receives feedback on the appropriateness of each stage of the problem solving strategy selected. Although Bitzer, Hicks, Johnson and Lyman (1967) indicate that there are many other types of teaching logic, Romaniuk (1970) notes that most of these are the blending of inquiry and tutorial logics. Romaniuk (1970) refers to such teaching logics as "General logic" (p. 24). To enable programmers to use these teaching logics, a special keyset called the PLATO *modeswitch*, was devised that possesses a matrix of keys that facilitate the entry of a program according to the logic selected (Bitzer, Hicks, Johnson & Lyman, 1967).

While the modeswitch helps the programmer enter the lesson according to a teaching logic, for the program to be comprehensible to the computer, it must be translated or *compiled* into some form that it recognizable to the computer. In this instance a version of FORTRAN was used as the basis of the compiler (Bitzer, Hicks, Johnson & Lyman, 1967). The compiler, introduced in late 1964, is known as CATO, or *C*ompiler for *A*utomatic *T*eaching *O*perations (Lyman, 1978). At about the same time as the introduction of

CATO, PLATO was modified so that editing of lessons could take place while other terminals were being used for instructional purposes (Lyman, 1978). By the summer of 1966, the on-line editor was altered so that editing of programs could take place from more than one terminal. This feature was known as MONSTER, or the *Multiple ON-line authorS Tape EditoR* (Lyman, 1978). While the creation of the modeswitch and a compiler enabled individuals without extensive programming skills to design lessons for PLATO, actual programming remained beyond their capabilities. Later developments to PLATO addressed this problem.

It may be asked why it is considered necessary to permit individuals who are naïve of computer programming to design PLATO lessons? Bitzer and Skaperdas (1971) state that the preparation of a good computer-based course, "is roughly equivalent in effort to writing a good textbook" (p. 24). Apart from editing and proofreading, few other specialized skills are required of a textbook author. To design a computer-based lesson, however, not only is the effort of writing the program required, but also the skill of being able to program it on the computer so that it will be delivered and will function in the ways intended. Given that writing a textbook is a demanding task, it is logical to assume that additional difficulties such as programming will dissuade many individuals from designing course materials for presentation by computer. By removing as many technical obstacles as possible, it is likely that more individuals will be inclined to design lessons for computer presentation. Bitzer and Skaperdas (1971) also note that an added incentive to designing course materials for computer presentation is that they will likely be inexpensive to reproduce and distribute and that royalties to authors will likely be higher than with textbooks.

By the summer of 1967, Bitzer and his associates developed a language for PLATO that enabled a designer of lessons to enter the course material into the computer by using English words and phrases according to a particular protocol, a teaching logic in this case. This language is known as *TUTOR*, and it is representative of a class known as authoring languages (Lyman, 1978). TUTOR may also be considered a *high-level* authoring language because it uses ordinary English words and phrases in a manner similar to conversation. Programming in TUTOR may be done on-line, so immediate editing of the program is possible. Although it is intended that authoring languages such as TUTOR eliminate the need for the lesson designer to possess knowledge of computer languages, a knowledge of English words that mean particular computer actions (commands) in the context of lesson design is necessary. Smith and Ghesquiere (1974) note that 200 special commands, in English, are included in TUTOR, although they indicate that in most instances, "much lesson material can be written with less than a dozen of these commands" (p. 55).

While it is likely that the TUTOR authoring language contributed to a greater development of lessons for PLATO, Bitzer, Hicks, Johnson and Lyman (1967) note that one of the most important factors restricting the deployment of computers for presenting instruction is economics. The authors state that while the PLATO III system could be used with at least 20 individuals, greater economic value would be obtained only when a single computer controls thousands of terminals. While this arrangement distributes the cost of the main computer widely, Bitzer, Hicks, Johnson and Lyman (1967) state that the PLATO III terminals were so costly that it would be prohibitive to consider them for an extensive system. Another limitation of these terminals is the difficultly in entering drawings. While arrow keys permit drawings to be entered, the method of creating the drawings is awkward and it may be argued that learning to use arrow keys adds to the difficulty of the intended task. A simpler means of creating drawings would likely reduce the difficulties in using a terminal. The electronic book comprises another limitation of the PLATO III terminal. Besides requiring valuable central processor time for the switching of signals to each display, a coaxial cable was necessary to connect each terminal to the computer so that the video image could be reproduced by the display. While this arrangement is satisfactory for terminals that are not too distant from the computer, the cost of coaxial cable becomes prohibitive when terminals are located many kilometres away. A terminal that does not require such elaborate communication with the computer could be connected to the computer through regular telephone lines. Such a terminal could be placed in most remote locations.

Design of the new terminal began in 1967, and was based on the principle of plasma display (Bitzer, Hicks, Johnson & Lyman, 1967; Lyman, 1978). A description of the new PLATO terminal is important, since it represents one of the first attempts at designing computer hardware specifically for educational purposes.

The display consists of two glass plates spaced a small distance apart, the space being enclosed and filled with a gas mixture composed largely of neon. The size of the display is approximately 8.5 inches square (210 mm^2). Lines of thin, transparent conducting material are deposited on the inner surface of each glass plate. A thin coating of a dialectric material is then deposited on top of the conducting lines. The lines are spaced 60 to an inch (25.4 mm) and the plates are oriented so that the lines on one are perpendicular to the lines on the other (Bitzer, 1976). In this manner an x-y matrix is formed with a resolution of approximately 512 by 512 lines. The deposited conducting lines function as electrodes. When sufficient voltage, usually in excess of 75 V, is applied to x and y electrodes, the gas in the immediate proximity of the intersection will become ionized. This ionized gas, or *plasma*, is visible as a reddish or orange dot. Energizing a number of electrodes results in a pattern of dots appearing. In some experimental prototypes the glass plates were held apart by an intermediate sheet of glass perforated with holes corresponding to the intersection points of the transparent conductors (Bitzer & Skaperdas, 1971). As well as serving as a spacer, the perforated panel isolates the plasma of discrete points, thereby preventing their coalescence. The perforated panel was omitted in subsequent versions, since the dielectric layer rendered the expensive perforated panel superfluous.

The dielectric layer isolates the electrodes from the gas. In this way a charge is propagated adjacent to each energized electrode on the dielectric layer. This charge, interacting with the plasma, maintains the ionization if a sustaining voltage is present. The charge also helps to extinguish the ionization immediately when the polarity of the main voltage is reversed and reapplied to the electrodes (Bitzer, 1976). To sustain the ionization of one or more points, a varying voltage in the form of a square wave with a magnitude below the ionizing voltage and a frequency of 100 kHz, is applied to all the electrodes. Once a point or a series of points is ionized by application of the main voltage, the ionization continues until the main voltage is reapplied to those electrodes in reverse polarity. The frequency of the sustaining voltage is sufficiently high so that a constant glow is visible to the observer. This variety of plasma display presents an image without a refresh signal from the computer (Bitzer, 1976). Bitzer (1976) also notes that this type of display, unlike CRT display, does not flicker and it produces images of high contrast that are more easily seen in a lighted room. Alpert and Bitzer (1970) report that the plasma display is also known under the trade name *Digivue*.

The transparent nature of the display permits projected images to be superimposed on it. While the superimposition of images was possible electronically in the earlier PLATO terminals, the procedure cannot be used with this type of plasma display. Instead, a special type of indexing microfiche projector was incorporated into the terminal. The projector consists of a fixed light source within the terminal housing. A microfiche, containing up to 256 images either in colour or black and white, each measuring one-quarter inch square (63.5 mm^2) and arranged in an array of 16 by 16 images, is supported in a moveable frame beneath the light source. The light source is arranged so that only one image can be illuminated at one time. A lens focuses the image and mirrors deflect the image onto the plasma display. A computer-controlled shutter mechanism determines when an image is projected on the display (Bitzer & Skaperdas, 1971).

The frame is supported by four rods. Two of the rods are arranged in parallel to support opposite sides of the frame. The ends of these rods are held by fittings which are also connected to two other rods. These rods are aligned at right angles to the first two. The microfiche can be moved along both the x and y axes with this arrangement (Bitzer, Johnson & Skaperdas, 1970). A series of four pneumatic cylinders with pistons of different stroke lengths are connected in a linear fashion to the end of one rod aligned to the x axis. A similar arrangement is installed on one of the rods aligned to the y axis. The ends of the cylinder arrays not connected to rods are fixed to the terminal housing. Each cylinder is connected by flexible tubes to a four-way valve, controlled by electromechanical means. A compressed air supply of approximately 8 pounds per square inch (55.16 kPa) is required to operate the pistons (Bitzer & Skaperdas, 1971). The valves and their controlling solenoids are designed so that each piston may be placed in one of two possible states, fully extended or fully retracted. One cylinder in each array possesses a stroke sufficient to move the microfiche by one row or column. The next cylinder permits the microfiche to be moved by two rows or columns. The following cylinder permits movement by four rows or columns, while the final cylinder permits movement by eight rows or columns (Bitzer, Johnson & Skaperdas, 1970). With this arrangement, the solenoids, valves and pistons convert digital electronic signals into binary linear motion, thereby enabling the computer to position any image on the microfiche beneath the light source. Bitzer (1976) states that an 8-bit code sent by the computer controls the positioning of the cylinders, 4 bits determining the row and the remaining 4 bits determining the column. Bitzer, Johnson and Skaperdas (1970) report that the pneumatic system proved reliable during testing and that the greatest access time for a given image was 0.5 seconds. Figure 83 (after photographs in Chambers & Sprecher, 1983, p. 9; Smith & Ghesquiere, 1974, p. 55) shows the appearance of a PLATO IV terminal with top removed, showing the arrangement of the microfiche and the controlling pneumatic cylinders.

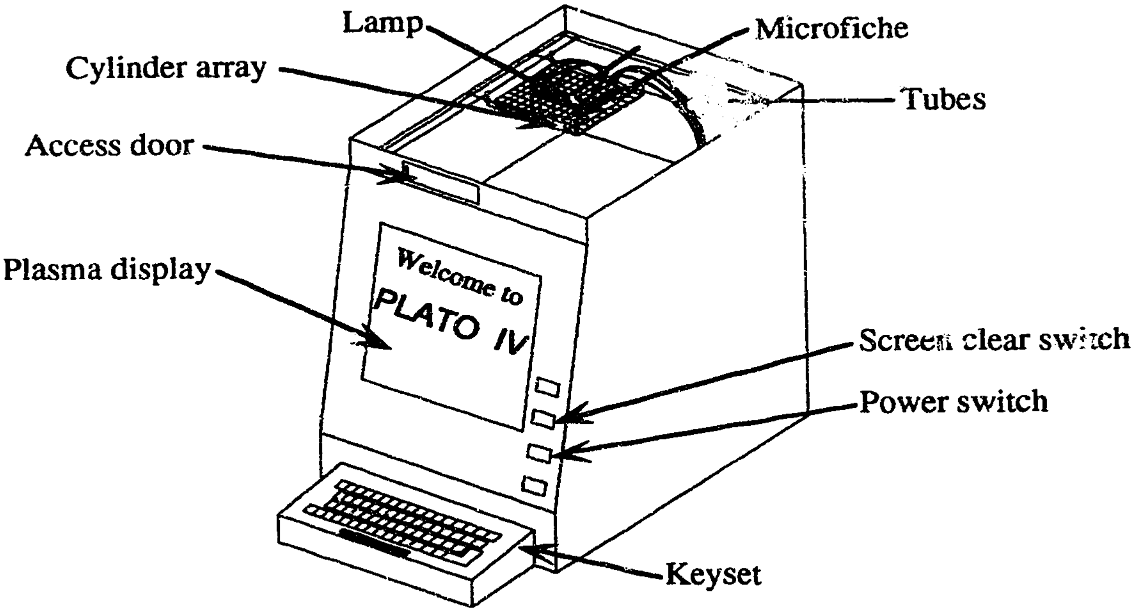


Figure 83. Appearance of a PLATO IV terminal with top removed

It is noted in a previous section that using arrow keys to indicate particular points on PLATO III terminals was found to be unsatisfactory and a more suitable means of indicating points was desired. The development of input peripheral devices for computers has been concurrent with the development of computers themselves. It is also noted in a previous section that optical pointing devices such as light pens were developed in the

1940s and were used with some computers. Although English, Engelbart and Berman (1967) describe the development of other pointing-type input peripheral devices such as mice, joysticks and a knee-operated unit, none can be used without first learning to manipulate or control the apparatus (psychomotor skill). It follows, therefore, that an input peripheral that does not require the learning of an additional skill is better suited to computer-controlled instructional systems. An example of such an input peripheral is a touch screen, consisting of apparatus installed in front of the display that is activated by the user touching the apparatus either with a finger or similar object. As well as not requiring the learning of a new psychomotor skill, touch screens can be used by both right-handed and left-handed individuals, and also by disabled individuals who are able to hold a stylus in their mouths.

While Handel (1971) describes an early British device called a *touch display* that uses an array of wires laid out in the form of a Cartesian coördinate system placed in front of the display screen, Bitzer and his associates used a different design. The apparatus devised employs an x-y grid pattern of infrared light emitting diodes (LEDs) and infrared-sensitive phototransistors mounted on a circuit board that is placed in front of the display screen or panel. Measuring 8.5 inches square (215.9 mm2) a total of 32 infrared LEDs are spaced evenly along the bottom and left-hand sides of the display, 16 along the bottom and 16 along the left-hand side. An equal number of infrared phototransistors are arranged in a similar pattern along the top and right-hand sides of the display. The entire array comprises a Cartesian plane divided into a matrix of 256 squares. In operation, a finger or a passive stylus such as a pencil is used to interrupt infrared beams on both axes. The lack of infrared light striking the corresponding phototransistors is interpreted by the computer as an indication where on the display the individual is pointing.

Collimation of the LEDs and the phototransistors is not necessary, since the controlling circuitry activates only one LED and its corresponding phototransistor at a time. The scan rate is sufficiently rapid so that a position is recorded even if the display is touched quickly (Ebeling, Goldhor & Johnson, 1972). Parallax is not a problem since the underlying plasma display is flat. While it is not stated why Bitzer and associates adopted an infrared version of a touch screen, this particular variety possesses no moving parts, so maintenance costs are likely lower than those for a touch screen with moveable components.

An element missing from the earlier PLATO terminals was the provision of aural information. One problem with presenting such information is synchronizing it with the appropriate visual material. Bitzer and his associates designed a random-access audio player on the same principle as the random-access microfiche projector incorporated into the PLATO terminal. This technology was selected primarily to obtain the fastest access time to discrete elements of the recording (Bitzer, Johnson & Skaperdas, 1970). The mechanism consists of a rim-driven turntable, 12 inches (304.8 mm) in diameter, that revolves at a rate of 75 revolutions per minute during access and 11 revolutions per minute during playback (Bitzer, 1976). The turntable is supported by an electrical drive mechanism. A vertical shaft passes through a hole cut in the centre of the turntable. The shaft possesses square-profile grooves, one running the length of the shaft, the other along the circumference. A square projection in the centre hole of the turntable is fitted into the vertical groove of the shaft. This arrangement enables the torque of the turntable to be transmitted to the shaft, while allowing the shaft to move up and down freely (z axis motion). The vertical shaft rests on an array of four pneumatic cylinders that are of a configuration similar to those used with the random-access projector.

The recorded information is located on a mylar disk coated with a magnetic medium. Information is recorded onto the disk in the manner of 64 radial tracks divided into 32 sectors (Bitzer, Johnson & Skaperdas, 1970). In the initial versions of this mechanism, the maximum diameter of the disk could be 12 inches (304.8 mm). Bitzer (1976) notes that subsequently, the maximum diameter possible was 14 inches (355.6 mm) and that the disks were interchangeable. Thirty-two optical marks are located along the circumference of the turntable and a photodiode is located near the disk to sense the passage of each mark. The disk is attached to a collar-like metal hub keyed into the helical groove of the vertical shaft. With this arrangement the disk rests normally on the surface of the turntable. In this position, the numerical order of the sectors on the disk corresponded to the optical marks on the turntable. A magnetic head is used to detect the information on the recording. The head is supported by a fixed arm positioned above the turntable and the arm is also connected to an array of six pneumatic cylinders that move the head across the disk radially. The head is positioned normally so that it is not in contact with the disk. This design feature reduces wear on both the head and the disk (Bitzer, Johnson & Skaperdas, 1970). The design of the apparatus enables the computer to select specific information for reproduction.

The disk and turntable usually revolve together. This is not the case when information from a particular track is reproduced. If, for example, track 45 in sector 14 is desired, the computer causes compressed air to be introduced into the required number of cylinders connected to the head. This action positions the head above the correct track. Proper sector location is achieved by activating the cylinders supporting the vertical shaft. The movement of pistons cause the shaft to move upwards. The disk then slips backwards on the turntable, since the disk and hub assembly are keyed into the helical groove in the shaft. The optical marks along the circumference of the turntable enable the computer to locate particular sectors. Once this action occurs, the head is lowered and the motion of the turntable allows the head to detect the recorded information at that location. Once the track is read, the air in the cylinders beneath the vertical shaft is allowed to escape, causing the shaft to return to its rest position. This action also returns the mylar disk to its appropriate location relative to the optical marks on the turntable (Bitzer, Johnson & Skaperdas, 1970).

As with the random-access projector, the audio unit requires compressed air as well as electricity. Air pressure of 15 pounds per square inch (103.4 kPa) higher than what was required for the random access projector, is necessary for the audio unit. Through testing, it was discovered that the access time for any particular track did not exceed 0.3 seconds (Bitzer, Johnson & Skaperdas, 1970). With a full-sized disk, a total of 8.5 minutes of information could be recorded. Stereophonic sound could be reproduced from an appropriately prepared disk if dual magnetic heads were used for the pickup (Bitzer, Johnson & Skaperdas, 1970). Alpert and Bitzer (1970) report that the design of the audio unit was intended to make it inexpensive to manufacture. To minimize the cost of a terminal, the random-access audio unit was designed as a separate, optional unit that could be purchased if required (Alpert & Bitzer, 1970). Like the terminal, a commercial version of the audio unit was produced subsequently by the Education & Information Systems Company. Francis (1976) reports that this version was smaller and it possessed a higher degree of reliability than the units produced at the University of Illinois.

While the planning and development of a new PLATO terminal began in 1967, a satisfactory prototype was not completed until 1971 (Bitzer & Skaperdas, 1971). Although the development of the new terminal was within the capabilities of Bitzer and his associates, mass production was not. The Magnavox company was selected to manufacture the new PLATO terminal (Lyman, 1978). These terminals were not compatible with the CRT-based PLATO III system, so a new system was devised. Designated PLATO IV, this version was controlled initially by a CDC 6400 series mainframe computer. With the new terminals and the larger capacity computer, it was contended that up to 4,000 terminals at a time could be operated (Alpert & Bitzer, 1970).

With the development of a new terminal that would reduce the cost of communication between the host computer and individual terminals and the development of a computer system that could support as many as 4,000 terminals, Bitzer and Skaperdas (1971) contend that the cost of PLATO per student was approximately 34¢ U.S. per hour. This figure is based on the cost of the computer ($4.5 million) 4,000 terminals ($7.5 million) the software ($1.5 million) as well as some miscellaneous costs such as the distribution network (Bitzer & Skaperdas, 1970). With the arrangement of a single computer controlling many terminals, the cost incurred by individual users would be minimal compared to the cost of purchasing an entire computer-based instructional system. Bitzer (1976) states that earlier cost estimates for PLATO were usually below the actual costs incurred and that the higher costs of the system, sometimes in excess of $2.00 per hour, dissuaded some educational institutions including schools, from using PLATO. Bitzer (1976) contends that further developments of hardware and courseware would reduce the cost of the system to 35¢ per hour by 1980, prompting the prediction that, "in view of rising educational costs, computer-based education is likely to be an attractive alternative to expanding educational needs" (p. 279).

Improvements were also made to the TUTOR authoring language, and an experimental configuration of the PLATO IV system was operational by 1972. Initial operation began with four terminals, but this number was increased to 250 by the end of 1972, with many of the terminals being located at remote sites (Lyman, 1978). Actual class instruction using the PLATO IV system began in 1973. To permit the further expansion of PLATO IV and to increase its efficiency, a CDC Cyber 73-24 model computer replaced the model 6400 in 1973. PLATO III was phased out during the same year (Lyman, 1978). The CDC Cyber computer differed greatly from computers used previously to control PLATO. Instead of a single processor, two central processing units (CPUs) were present, each with a capacity of one million instructions per second (Mips) but incapable of performing parallel processing as the term is defined at the present time (Bitzer, 1976). The CPUs are connected to 10 peripheral processing units, specialized coprocessors controlling input and output to the terminals and controlling peripheral devices (Bitzer, 1976). This complex configuration was used to permit a single computer to control many PLATO terminals at widely scattered sites. Communication between the Cyber computer and the remote sites was achieved through a network using digital television signals and microwave relays (Bitzer, 1976). Communication between the remote site controllers and individual terminals was through ordinary telephone lines. An information transfer rate of 1260 bits per second (bps) was used on these circuits (Bitzer, 1976). To increase the capacity and the efficiency of PLATO IV further, a CDC model 6500 computer was used with the Cyber computer beginning in September 1976 (Lyman, 1978).

While the PLATO IV terminals and peripheral devices were designed for instructional purposes specifically, many problems became apparent with the system and its components once implemented. Francis (1976) notes that general maintenance and repair of the equipment located at remote sites was sometimes a problem if the site was located a great distance from the University of Illinois where the repair crews were located. The telephone lines used to connect terminals to a site controller were subject to occasional interference, causing shifted or distorted images on the plasma displays. Line interference could also cause the system to generate spurious characters, move the user forward as though a correct response had been entered, branch the user into a remedial section as though an incorrect answer had been entered, or cause the entire terminal or remote site to fail (Francis, 1976). Although the design of the terminal permitted users to replace microfiche, improper handling could scratch the surface, degrading the quality of the projected image. If the microfiche was not inserted properly into the holder inside the terminal, the microfiche could touch the projector bulb, causing the microfiche to melt. Francis (1976) notes that this problem was rare and that, "the insertion of the mounted microfiche into the terminal seems relatively easy even for grade school children" (p. 9). Some malfunctions resulted in improper operation of the terminal rather than a complete operational failure. A sticking pneumatic valve or piston in the microfiche projector results in an incorrect image being displayed (Francis, 1976). Besides confusing the user, presenting erroneous information as correct runs contrary to many of the theories of learning mentioned to this point. A partially burned-out projector bulb, while functional, is liable to emit a limited spectrum of light at a reduced intensity. This condition may shift the colours of coloured images. While colour shifts are not serious in most applications, the condition is unsatisfactory in many medical applications where a diagnosis may depend upon the colours of particular tissues. It is for the reason of poor and inconsistent reproduction of colour that the PLATO IV terminal was considered unsatisfactory for many aspects of medical instruction (Francis, 1976).

The supplies for the terminal also caused problems. Francis (1976) notes that the difficulty and expense in securing an adequate compressed air supply prompted some remote sites to design lessons that did not require photographs. Production of microfiche was frequently difficult, expensive and time-consuming. Not all locations were capable of preparing suitable microfiche because of the odd size used and because of the special processing techniques required (Francis, 1976). The high-contrast film used presented other problems. Medical X-ray images that require a faithful reproduction of grey tones, as well as images with fine detail located in high-lighted areas could not be reproduced on the microfiche satisfactorily.

Through experience, it was found that the registration of vectors and labels over a projected image was difficult since the alignment of each machine differed. Incorrect registration results in the projected image backlighting the plasma display. Francis (1976) notes, "Plasma displays backlit with white or light-colored backgrounds lack contrast and are very difficult to read" (p. 5). While the problems encountered with the microfiche projector were not of concern to all users, it is apparent that in some instances the design of instructional material was constrained by technical limitations rather than by pedagogical practice and theoretical considerations.

Problems were also encountered with other peripheral components of the terminals. The design of the touch panels resulted in both some pedagogical and programming problems. Francis (1976) notes that the grid pattern created by the infrared beams was coarse enough so that the fingers of small children and some small styli did not always interrupt beams when the terminal screen was touched. Another problem caused by the design of the panel was that it causes a beep tone to sound whenever a beam is interrupted. While it may be contended that this feature prevents frustration in the user through not knowing whether or not a touch has been registered, the tone may still cause confusion if particular programming techniques are not followed. Francis (1976) reports that in many lesson types, "there are areas of the screen which are not expected to be touched; they do not correspond to either a correct or incorrect response, but rather are completely undefined" (p. 25). Touching an undefined area results in a beep tone, but the input may not be recognized by the program. Francis (1976) notes that many users who experience this phenomenon, "find the beep so reinforcing that they will touch all over the screen regardless of what is occurring" (p. 26).

The design of the touch panel did not conform to the layout of the display for programming purposes. Francis (1976) states that the touch panel is laid out on a 16 by 16 grid, while the plasma display is laid out on a 32 by 64 grid, "The conversion between these two systems is a tedious, mistake-prone task for the author" (p. 30). Francis (1976) also notes that the TUTOR authoring language permits inexperienced authors to make mistakes in programming for the touch panel. By not being aware of the operation and the limitations of the touch panel, Francis (1976) notes several conditions that may occur to frustrate users,

> (a) allowing multiple inputs when only single inputs make sense, (b) inappropriately choosing whether or not to allow additional touch inputs during the presentation of feedback, (c) failing to provide visual feedback concerning the touch input mode (i.e., when the student touches a word or response, circle it, flash it, or otherwise confirm the input). (p. 28)

Francis (1976) claims that the last point mentioned is perhaps most important when the lesson is intended for young children. It is contended that by acknowledging an input through some visual indication, the tendency of young users to respond to a question or other stimulus is reinforced. While the appropriateness of such a behavioristic approach may be argued, the concern noted by Francis (1976) illustrates the complex interaction between equipment design, methods of pedagogy and theories of learning. The difficulties in coördinating the touch panel with the plasma display and the preparation of suitable programming techniques, illustrates how the creation of an instructional device by engineers and designers does not ensure that pedagogical and theoretical concerns will be addressed satisfactorily.

While the number of terminals connected to the PLATO IV system continued to grow in spite of hardware and programming problems encountered, Bitzer and associates found that they could not operate and maintain the system while trying to develop PLATO further. In early 1976, therefore, the marketing of the PLATO system was taken over by the Control Data Corporation (CDC) a company that not only supplied the last three controlling computers, but which had also been one of the largest corporate sponsors of the PLATO program (Lyman, 1978).

Although PLATO IV terminals use a plasma display to minimize the cost of the system, CRT technology had developed to a point where it was no longer inferior or more costly than plasma displays. This factor is important in view of the difficulties in preparing microfiche for PLATO IV terminals. Other factors mentioned in previous sections, such as specialized maintenance and the necessity of an appropriate compressed air supply, likely contributed further to CDC's decision to adopt a CRT-based terminal for their PLATO system.

The CDC PLATO system used the existing PLATO IV hardware configuration initially, but soon introduced a CRT-based terminal. Referred to as the *Information Systems Terminal* (IST) the apparatus contains a CRT measuring 8.5 inches square (216 mm2) an integral keyboard, a microprocessor with 6 k Bytes of Read Only Memory (ROM) and up to 16 k Bytes of Random Access Memory (RAM) and the ability to accommodate various input and output peripheral devices (Rahmlow, Fratini & Ghesquiere, 1980). While the layout and configuration of this terminal is similar to the terminal used with PLATO IV, the CRT-based terminal cannot accommodate projected images. Instead of combining textual information with pictorial information on one display, the CDC PLATO system presents pictorial information separately by using peripheral devices such as video disk players. The infrared-type touch panel was replaced by an optional touch screen overlay (Rahmlow, Fratini & Ghesquiere, 1980). While the reason for abandoning the infrared-type touch panel is not stated, it is likely that the light emitted by the CRT interferes with the proper functioning of the phototransistors.

The touch screen is similar in configuration to the touch panel. The screen consists of a frame that holds two pieces of fine mylar mesh. One piece is designed to rest against the surface of the CRT, while the other is held so that it is bowed away from the display. In this way the two pieces are separated. An array of 16 conductors is contained in each piece of mesh. In the mesh resting against the CRT, the conductors are arranged vertically as columns, while the conductors in the other piece are oriented horizontally as rows (Control Data Corporation, 1979). A passive stylus such as a finger or the end of a pen is used to deflect the mesh closest to the user towards the CRT. If sufficient pressure is brought to bear, then contact is made between the two pieces of mesh, completing a circuit at that point. Through polling circuitry, the terminal is able to ascertain the coördinates of where the two pieces of mesh are in contact. Although the mesh-type touch screen eliminates some of the problems encountered with infrared touch panels, new problems were introduced. One of the claimed advantages of PLATO is that it can be used in remote sites with minimum supervision. A result of this arrangement is possible abuse and vandalism of the hardware. The mylar mesh is particularly susceptible to damage from razor blades and from the flames and heat of butane lighters and cigarettes (Author's observations).

While Bitzer and associates envisaged a world-wide PLATO system driven by a single master computer, Conway (1976) claims that cost and technical considerations prompted CDC to sell autonomous or *stand-alone* systems to, "organizations and institutions with extremely large education and training requirements" (p. 3). The cost of such installations, ranging from 5 to 6 million dollars, was too expensive for most schools and school jurisdictions. The PLATO system remained popular with many companies, the American military, several universities and wealthy instructional and training institutions. Factors contributing to this popularity include the availability of an authoring language, TUTOR, as well as a large selection of ready-made courseware. A PLATO course catalogue (Control Data Corporation, 1980) lists 27 subject headings including Astronomy, Aviation, Chemistry, Computers, Health Services, PLATO topics and Veterinary Medicine. Over 730 individual courses are listed along with the title, author, intended users, goals, topics covered in the lesson and an abstract. It should be noted that most of the courses available were designed and intended for adult learners. The average time required to complete the lesson is also listed. The time intervals range from ten minutes for some introductory lessons, to times in excess of 100 hours for some elaborate courses. Some lessons are not presented entirely on the PLATO terminal. The description of each lesson also includes a listing of the media required for it, such as textbooks and video disk machines, and percentage of the lesson each medium requires.

Although some lessons simply present screens of text to read and the occasional question with remedial branching routines to make sure that the user is actually reading the screens, other lessons employ different presentation and instructional techniques. In this way, PLATO can function as a programmed instruction-type teaching machine, or it can present information and instruction in more sophisticated ways.

One such method is simulation. It is not always possible or desirable for the user to perform some experiments and procedures in reality because of danger, cost, time and the unavailability of conditions and materials. Provided that the lesson is programmed appropriately, PLATO can simulate an operation or event in various degrees of reality or *fidelity*. In a chemistry lesson, for example, a user may be given the choice of adding one of several reagents to a prepared solution. While an incorrect choice may result in an explosion, neither the user or the laboratory apparatus is damaged. In the case of events or procedures that require large amounts of time, the simulation can accelerate the process so that the outcome occurs sooner than normal. While this method of instruction is useful especially for indicating the outcome of particular actions and selections, it is not appropriate for instructing correct psychomotor skills, since the fidelity of the simulations possible with PLATO is limited by technology. Further discussion of simulations and simulators may be found in Chapter VIII.

Another instructional strategy possible with PLATO is the use of games. As a lesson or component of a lesson, games may be designed to instruct while the game is played. PLATO lessons may also be constructed to present drill or similar repetitive exercises, such as those that might be useful for keyboard training. Various examination types may also be prepared either as a discrete lesson or as a component of a lesson that uses other instructional strategies.

The wide variety of available PLATO lessons and the different of methods of instruction capable with the system are among the most important factors that contributed to the longevity of the PLATO system. Flexibility is also an important factor that has enabled PLATO to outlive most other main-frame computer-controlled instructional systems. By the late 1970s, changes in computer and electronics technology enabled PLATO to be made available to schools at lower cost than was possible previously. These same changes made most main-frame computers obsolete for operating instructional systems. This development in turn, led to the abandonment of the idea that a single large computer controlling an extensive network of dedicated terminals was the most economical deployment of computers as instructional devices. The major technological change was the introduction of the inexpensive microprocessor which led to the introduction of correspondingly inexpensive microcomputers. A large initial capital investment is required, nevertheless, for either a main-frame computer system or for a class or school set of microcomputers.

Lyman (1978) notes that the Computer-based Education Research Laboratory (CERL) at the University of Illinois continued to develop PLATO independently of CDC. A new system referred to as *PLATO V* was developed to augment display capability while diminishing the time required by the terminal to access the main computer (Brenner & Agee, 1979). Lyman (1978) notes that a new terminal referred to as *Plato Programmable Terminal* (PPT) was placed in production by the end of 1977, and that 100 of these terminals were installed on the existing PLATO IV system. The PPT or PLATO V terminal also uses a plasma display. Instead of being a *dumb* terminal like its predecessors, the PLATO V terminal contains an Intel 8080, an 8-bit microprocessor, and volatile storage of 8 k Bytes random access memory (RAM). Non-volatile memory consists of 16 k Bytes read only memory (ROM) and either one or two single-density floppy diskette drives (Brenner & Agee, 1979). With this configuration, it is possible for the PLATO V terminal to function as a stand-alone computer with a minimal need of communication with the controlling computer. In practice, the terminal accesses the main computer for course selection and user registration initially. Next, the entire lesson selected is downloaded to the terminal and communication with the main computer is discontinued until the lesson is complete or the user wishes to quit. At these junctures, the main computer is accessed to record information such as grades and/or the position of the user in an uncompleted lesson.

The terminal may also be used for authoring and for editing existing programs. Besides storing materials in the main computer, the author may also store the information on floppy diskettes locally. Brenner and Agee (1979) state that in spite of new features, the PLATO V terminal did not become as popular as expected. Several factors are likely responsible for this limited popularity. First, legal requirements restricted the number of University of Illinois PLATO installations and terminals, likely to minimize competition with the CDC system. Second, while most lessons could be downloaded to the terminal, considerable time was usually required to do this, causing a delay that could result in user impatience and frustration. Third, to take advantage of the microprocessor, a new version of the TUTOR authoring system had to be developed. Brenner and Agee (1979) state that a fully operational version of the language, called *MicroTUTOR*, was not available immediately with the new terminals, and that the language was not, "clearly documented, or easy to use" (p. 46). Fourth, it is likely that some authors did not desire to create courseware for this terminal, since most of this courseware would be incompatible with the PLATO IV terminals (Brenner & Agee, 1979). Fifth, while the PLATO V terminal could function as a stand-alone computer, it could not be used for applications other than PLATO. Being a dedicated terminal meant that in some environments, such as in most public schools, it would likely not be used most of the time, unlike some other microcomputers that can be used for a variety of operations and purposes.

The advent of the microcomputer enabled many schools to obtain powerful, multipurpose machines for less cost than the installation of dedicated computer-based instructional systems. In response to these changes in technology, CDC publishing, a subsidiary of CDC, prepared PLATO lessons that could be run on most popular microcomputers of the late 1970s and early 1980s (Control Data Publishing, 1983). In consequence of the rise in use of microcomputers, most PLATO installations were decommissioned. While PLATO continues to be used with some microcomputers, the instructional system has evolved into something completely different from the system devised originally by Bitzer and associates. Although PLATO represents an adaptable and long-lived computer-controlled instructional system, other such systems did not endure because of technical, pedagogical and theoretical considerations.

Talking Typewriter/Edison Responsive Environment

About the time PLATO I was introduced, other engineers, computer scientists and educators became interested in using computers as part of new instructional devices or to improve existing examples. Beginning in the mid 1950s, Omar Khayyam Moore, a professor associated with several educational institutions, became concerned with attributes of learning in pre-school and in young school-age children. Moore (1980) states that from his studies he developed methods of enhancing learning in these groups. Steg and Schenk (1977) claim that Moore's interest in studying learning in young children came about in 1959, as the result of his desire to teach his two-year-old daughter to read. The authors also state that Moore developed a method of instructing reading that uses an electric typewriter, a tape recorder and a slide projector. This account of Moore's work is similar to B. F. Skinner's (1983) description of the conditions contributing to the invention of his first teaching machine (see Chapter VI).

Whichever account about the factors leading to the invention of Moore's instructional device is correct, it is evident that Moore developed a major pedagogical strategy from his observations and studies; instruction must be individualized using a specialized environment. In such an environment that possesses a limited number of stimuli or sources of stimuli, it is contended that the individual discovers what is intended by the instructional designer, without the provision of extrinsic rewards or punishments. Some form of feedback is provided, however. In this manner, it is anticipated that the individual will learn specific items of information as well as learning the relationships and associations between them. Environments designed in this way are referred to by Moore (1962; 1964) as *autotelic*.

It might appear that Moore's strategy is another manifestation of Skinnerian behaviorism, a view shared by Glaser (1965) who notes that the reinforcement is in the form of control over the physical environment. It is important to note that the purpose of Moore's controlled environment is not the shaping of emitted responses to obtain a specific behavior pattern. The method is intended to encourage the individual to explore the environment in such ways that the information it contains will be discovered and learned by the individual. In this instance, emitted responses are used as a means of attaining a broad goal rather than a series of specific goals that will be concatenated subsequently, as in the manner of linear programmed teaching machines (see Chapter VI). Moore (1962) also notes that an activity is autotelic if its motivation is intrinsic rather than dependent upon extrinsic motivators. Moore (1980) states that the purpose of using a method that is responsive to the actions of the user, "is to change (possibly to enhance) the emotional-cognitive state of the user by virtue of being involved with it" (p. 15). The methods used by Moore are similar in principle to those used by Quintilian (see Chapter II). Like Quintilian, Moore's method teaches the recognition of individual letters. Moore does this by relating concrete actions to iconic symbols and auditory stimuli simultaneously.

Moore's method uses machines that require interaction with the user, rather than passive objects such as toy letters. Moore (1965) contends that most adults possess a socially-induced bias against machines, "man's long experience with machines has led him to conceptualize them as a kind of nonhuman or subhuman force... scientists tend to place machines under the rubric 'apparatus' and to speak of scientific 'instruments' rather than machines" (p. 5). Moreover, Moore (1965) states that young children are unlikely to possess such biases, and that most experiences that they have with machines such as television is pleasurable.

The main component of Moore's system is an electric typewriter. This machine possesses an advantage over the manual typewriter used by Ordahl and Ordahl (1915; see Chapter IV) since light pressure is required to activate the keys of an electric typewriter and its design prevents more than one key from being pressed at once. While Steg and Schenk (1977) note that Moore used several discrete machines in the initial design of his system, he did not possess the technical knowledge necessary to design an apparatus that could either provide aural feedback or could control the interaction of the machines with the user. Hanson and Komoski (1965) note that in the first versions of the system, aural feedback and control of the system were provided by an obscured human instructor. In partial defence of this design of his system, Moore (1980) states, "In 1960 the technological resources were not at hand to construct and operate learning centres that could outperform conventional educational systems" (p. 18). While this position may be disputed in view of the prior developments of computer-controlled instructional devices by Pask and others, it is evident that most educators at that time did not possess a knowledge of technology sufficient to design instructional devices controlled by computers. To design such a system, collaboration with knowledgeable individuals was necessary. Moore (1980) states that a computer-controlled version of his system was constructed in the early 1960s by Richard Kobler, an electronic engineer. Moore (1980) notes that Kobler designed two of his own instructional devices, the *Talking Page* and the *Voice Mirror*. These two devices are also intended to be responsive in the manner of the Talking Typewriter, since all provide some form of aural feedback. The Talking Page and the Voice Mirror, however, are not computer controlled, and both may be considered teaching machines according to the definition presented in Chapter I.

For the Talking Typewriter to possess a *responsive* or *clarifying* environment (Moore, 1980) the electric typewriter and any other components required for feedback or interaction with the user are placed in a sound-proofed, air-conditioned booth that limits the stimuli available to the user (Steg & Schenk, 1977). Once in the booth, the child is permitted to do whatever he/she pleases. Usually, the child will press keys on the typewriter and this will cause several events to occur. Firstly, the particular key depressed will cause the corresponding letter to be printed on paper in the typewriter. This may be considered visual or iconic feedback. Aural feedback is provided simultaneously. This is provided by a random access audio system possessing 768 tracks containing information in six languages, all under the control of a dedicated digital computer (Moore, 1965; Garner, 1966). The computer is controlled by magnetic program cards read by two separate pickup heads (Cleary, Mayes & Packham, 1976). One side of the cards possess magnetic media containing both the program codes and the audio messages. The other side of the cards may be printed with words or other information that is to be presented in a viewing window.

The feedback consists of an aural description of the key pressed, presented to the user by a speaker adjacent to the typewriter. Pressing the key labeled *x*, for example, results in a track being played back, either of the name of the letter or its phonetic pronunciation. Similarly, if the space bar is pressed, a recording stating *space* will be played. The system also possesses computer-controlled rear-projection apparatus, a window where textual material may be presented, and a microphone to permit the user to record sounds (Garner, 1966; Cleary, Mayes & Packham, 1976). The attribute of apparent or *virtual* speech, led Moore (1965) to refer to his machine as the *Talking Typewriter*. Further to his contention that young children do not possess *a priori* concepts about the nature of machines, Moore (1965) notes that many three-year old children are not surprised that the machine talks back, and many attempt to carry on a conversation with it.

Garner (1966) notes that although Moore designed the machine independently of commercial enterprises, the complexity of the system and its consequent cost, resulted in further developments being undertaken by the McGraw Edison Company at their Thomas A. Edison laboratory. The trade name of the system is known as the *Edison Responsive Environment* (Moore, 1965; Cleary, Mayes & Packham, 1976). Steg and Schenk (1977) state that the first commercial installation of the Edison Responsive Environment occurred in 1963.

The operation of the system is dependent upon two major factors, the subject matter being taught, and the age and capabilities of the user. To teach the association between particular letters and their names or sounds, the user is permitted to press keys at random. Each key press results in both visual and aural feedback. After a given amount of practice, determined by a human supervisor or by the computer through principles of fuzzy logic, in a manner similar to the way fuzzy logic was used by Pask, the keyboard is disabled and the system then presents the user either with the name of a letter or its sound. Following this presentation, the keyboard is reactivated and the system waits for the user to press a key. Pressing the correct key results in feedback that the key press is correct. Another letter or sequence of letters is then presented, the complexity of subsequent trials being dependent both upon the previous responses of the user and the parameters of the program or human supervisor. An incorrect key press results in the identification of the key pressed as well as a re-statement of the desired key or sequence of keys (Moore, 1965; Garner, 1966). With this method, the user is permitted to discover the correct response, but is given some feedback as guidance to the desired response.

Cleary, Mayes and Packham (1976) note that if the user is too young to recognize the letters on the keys, a different method of instruction can be used. Like the method used by Ordahl and Ordahl (1915) covers of nine different colours are placed on the keys of the electric typewriter. Each fingernail of the user is painted to correspond to one of the nine colours. The user is instructed to press each key only with the finger whose fingernail colour matches the key. In this manner, the user is taught correct keyboarding technique beginning with the first experience. At the same time, as each key is pressed, the letter is printed on the paper and its name is played back by the machine (Cleary, Mayes & Packham, 1976). The anticipated goal of this method is that the user will become familiar with the letters and with correct typing technique.

Reading may be taught by presenting textual material in the viewing window. Cleary, Mayes and Packham (1976) note that the material may be single letters, individual words, or up to four lines of complete sentences. By means of a red pointer, moved across the program card likely by mechanical means, the user can observe specific words while they are *read* by the computer. The user is thus shown the connection between sounds of particular letters or words and their printed appearance. Using the microphone, the user may also record his/her pronunciation of words or letters and may, in the manner of a language laboratory, compare their recording with the master recording (Cleary, Mayes & Packham, 1976). This instructional mode is intended to facilitate improvement in pronunciation (Garner, 1966).

Garner (1966) contends that studies comparing the efficacy of instruction between the Talking Typewriter/Edison Responsive Environment and traditional classroom methods indicate that measured achievement in reading is higher among those individuals who received instruction via the Talking Typewriter. Cleary, Mayes and Packham (1976) dispute this contention, citing several studies that do not find the Talking Typewriter to be more effective than traditional teaching methods. One problem with assessing the efficacy of any instructional device is obtaining a sufficient sample size. The studies summarized by Cleary, Mayes and Packham (1976) suggest that few Talking Typewriters were used in schools. Steg and Schenk (1977) also state that the use of the Talking Typewriter was limited. While Moore (1980) acknowledges that the Talking Typewriter attained limited deployment, he notes that it was obsolete technologically by the end of the 1970s.

It is likely that cost was one of the major factors limiting the deployment of the Edison Responsive Environment. While Moore (1980) concurs with this assessment he also notes other factors that contributed to the system's limited use. Moore (1980) states that some individuals considered the Talking Typewriter to be, "an educational panacea", an exaggerated impression likely induced by advertising and sales techniques not under Moore's control. After sale consultation and guidance seems to have been limited, since Moore (1980) notes that some purchasers used it in ways that were not intended, resulting usually in dissatisfaction with the apparatus.

While Cleary, Mayes and Packham (1976) also contend that cost was a major factor limiting the deployment of the Edison Responsive Environment, they note that the machine's dependence upon the facility of the user to perform specific psychomotor skills was also a limiting factor, "the use of a keyboard response presents young or retarded children with a much greater initial difficulty than a touching or button pressing response in a simple matching-to-sample task" (p. 55). This observation is similar to the findings of LaZerte (1933) with respect to his problem cylinder. Although he established that his device could teach, he also discerned that to learn the intended material from the problem cylinder, the user must first learn a different and largely irrelevant task, the operation of the machine. The conclusion was that the problem cylinder added to the difficulty of the intended task. A similar condition exists with the Talking Typewriter. Although each of the skills the system can teach may be useful to most individuals, it is arguable that it is sound pedagogy to attempt teaching several skills simultaneously, such as keyboarding techniques with letter recognition.

In spite of the technological innovations of the Edison Responsive Environment and its ability to operate in a number of different instructional modes, it appears that the aforementioned factors contributed to the eventual cessation of manufacture. Moore (1980) states,

> If we have learned anything in nearly twenty years, it is that educational innovations must be carried out with quality control. It is not enough to assess innovations just by the testing of results. The educational process itself has to be monitored and supervised by those who understand it. All too many educational innovations fail once they get out in the field. (p. 17)

The idea of providing aural feedback to enhance the forming of associations between names, sounds and symbols has not been abandoned, however. Although Moore (1980) makes no mention of new devices based on the Talking Typewriter or its principles of operation, there are several personal, computer-controlled devices available at present that function in ways similar to it.

Dedicated computer-controlled instructional devices

The term *dedicated* is used in this context to refer to devices that are designed for one main purpose only, as opposed to devices intended for several purposes. Examples of multipurpose devices include microcomputers, since they may be set to function as, among other things, word processors, drawing or drafting machines, simulators or game machines.

One factor contributing to the high cost of the Talking Typewriter/Edison Responsive Environment was the expensive controlling computer. By the late [illegible]ry large scale integrated circuits (VLSI) were being manufactured commercially. [illegible]e of integrated circuit contains the equivalent of many thousands of discrete [illegible]ents such as transistors, resistors and capacitors. In consequence, entire central processors can be contained in case only a few millimetres in size. Space required for components is also saved when integrated circuits are used. Such small circuitry also requires much less power than equivalent circuits constructed with discrete components. Considering these features of integrated circuits, it is not surprising that small, portable, dedicated computer-controlled instructional devices began to be manufactured by the late 1970s. Among the first was an electronic calculator from Texas Instruments, called the *Little Professor*. Besides functioning as an arithmetic calculator, the apparatus could also present arithmetic quizzes. The Little Professor was marketed primarily as a toy that might also be considered educational. The commercial success of this device led to the marketing of many other versions and types.

Speak & Spell

Using a single integrated circuit microprocessor, Texas Instruments designed one of the first portable computer-controlled dedicated instructional devices similar in operation to the Talking Typewriter. Called *Speak & Spell* and introduced in the late 1970s, the apparatus was designed primarily for home use by young children as an educational toy (Marshall, 1979). The device consists of a small plastic case approximately 250 mm long, 174 mm wide by 30 mm thick, housing the microprocessor, a display consisting of several seven-segment light emitting diode (LED) units (later versions employ a liquid crystal display instead) a number of keys, a loudspeaker, a battery vault to hold four C-type dry cells, and a socket for the connection of additional read only memory modules (ROMs). Twenty-six keys are labeled with letters of the alphabet, arranged in alphabetical order. Two keys control whether the machine is on or off, while other keys are intended for special purposes, such as entering composed words or having the machine repeat its most recent statement. Marshall (1979) notes that the Speak & Spell ROM contains a vocabulary of 200 words and that the machine generates a male-sounding voice.

Like the larger Talking Typewriter, Speak & Spell can be used in several instructional modes. One mode, called *Mystery Word*, is an instructional game. The computer first displays an incomplete word, one containing several blank spaces. The object of game is for the user to enter the correct letters. Every letter entered causes the computer to speak the name of the letter. A correct selection results in the letter appearing in the blank space and the generation of a sequence ascending tones, signifying that the selection is correct and likely providing positive reinforcement to the user. An incorrect selection also results in the computer reciting the name of the letter. This is followed by a series of descending tones with no letter being placed in a blank position. These actions signify that another try is necessary. If the user enters all the correct letters, the computer states, "you win". After seven incorrect choices, the computer states, "I win" and it then reveals the missing letters in the word.

The Speak & Spell can also present drills in varying levels of difficulty. In most instances, a sequence of ten words is displayed, each accompanied by computer pronunciation. Next, the unit again speaks the first word in the sequence and requests the user to spell it. After composing the word on the display by pressing the lettered keys, the user causes the word to be evaluated by pressing the *enter* key. At this point, the computer responds verbally. A correct entry results in the statement "that is correct, now try ..." and the next word in the sequence is presented. An incorrect entry results in the computer stating "that is incorrect, try again, spell ..." the same word is repeated. The user is given three chances to enter the correct response before the next word in the sequence is presented. If the user does not hear the word when it is stated by the computer, the *repeat* key may be pressed. The computer keeps a record of the performance of the user and the final score is announced at the end of the quiz. The nature of the quizzes and exercises can be altered and expanded through the use of additional ROM modules.

At a retail price of under $80.00 U.S., the Speak & Spell is inexpensive compared to the other computer-controlled instructional devices discussed to this point. Although the Speak & Spell might appear ideal for schools because of its low cost, attraction, motivation, small size and portability, several problems have been noted with its use in schools. Marshall (1979) states that the first versions of the Speak & Spell did not have provision for an external power supply. This design is disadvantageous, since there is a frequent replacement cost for batteries. Marshall (1979) also notes that the early versions could not be used in a class, since there was no provision for headphones. The sound from the loudspeakers is liable to disturb or distract other students. Both of these problems were rectified in later versions. Quality control appears to be a problem as well. Marshall (1979) notes that keys on some units stick and the voices of some machines sound muffled. Terrell and Linyard (1982) express concern about the efficacy of the Speak & Spell. They contend that it was designed primarily for entertainment and profit to the company rather than for educational purposes, "The 'educational evaluation' of these machines is not the responsibility of the manufacturer, their main *raison d'être* is simply to sell as many machines as possible" (p. 59). While this criticism may be applied to many commercially-produced instructional devices, evidence is noted previously to show that the manufacturer did alter the design of the machine to better suit the needs of educators. The question of the efficacy of an instructional device is not resolved easily.

While there are many studies indicating that the use of Skinnerian-type teaching machines improved the level and speed of learning in particular individuals, there are many other studies indicating that teaching machines were ineffective and based on a theory of learning inappropriate for human beings (see Chapter VI). A similar condition exists when considering studies concerning the efficacy of other types of instructional devices. Recent advertising literature from Texas Instruments (1990) indicates that the design of the Speak & Spell as well as some other dedicated computer-controlled instructional devices were collaborative efforts between the engineers of the company and "learning experts". Who the learning experts are is not revealed and neither is the extent of their influence upon the design of the apparatus. It appears that Texas Instruments considers their instructional devices to be sound pedagogically, since they are marketed by themselves, unlike some teaching machines that are marketed in conjunction with traditional and more established instructional media such as encyclopedias (see Chapter VI).

It is noted previously that the keyboard layout of the Speak & Spell follows alphabetical sequence. While this arrangement does not require the user to become acquainted with standard keyboarding techniques, it raises the question of whether or not learning to use a keyboard arranged in this way will interfere with subsequent learning of standard keyboard techniques. The position that information learned previously may interfere with the learning of similar information subsequently, termed *proactive interference*, is established from the findings of experimental psychological studies, some dating from the nineteenth century (Ebbinghaus, 1885/1913; Keppel & Underwood, 1962; Lefrancois, 1982). It should be recalled that the Talking Typewriter was able to instruct correct keyboarding techniques initially, thus preventing the development of incorrect psychomotor patterns that would require subsequent *unlearning*. It does not appear, therefore, that the concept of proactive interference was considered in the design of the Speak & Spell. It may be contended that the motivational benefits of the Speak & Spell and the intent of the unit to be used primarily as an unsupervised toy outweigh possible future problems caused by proactive interference. While the standard or *qwerty* keyboard may be rendered obsolete someday, it continues to be the predominant means of input to most microcomputers and to many business machines. It seems logical, therefore, that instructional devices designed to facilitate learning in one subject area should not compound the difficulty of subsequent learning in other areas.

Following the commercial success of Speak & Spell, other dedicated computer-controlled instructional devices have been marketed by Texas Instruments and other manufacturers. Examples include: *Electronic Learning Machine* from Coleco Industries, similar to Speak & Spell, presents math problems and music lessons in addition to spelling games; *Digitor Skillmaster* from Centurion Industries, designed to present arithmetic drill in a manner similar to the Little Professor; *Quiz Wiz* from Coleco Industries, designed to present quizzes on a variety of topics, depending upon the cartridge ROM used; *Super Speak & Math* from Texas Instruments, presents arithmetical and mathematical concepts by means of aural descriptions and by combining iconic and symbolic representations of numbers; and *Voyager* also from Texas Instruments, worn as a headset which presents information and questions aurally and requires a one or two word verbal response (Neumann, 1983; Texas Instruments, 1990).

Other computer-controlled instructional systems

SOCRATES

While the Talking Typewriter and PLATO were being developed, Lawrence Stolurow, a professor at the University of Illinois, created his own computer-controlled instructional system in collaboration with IBM. First made operational in 1964 (Stolurow, 1967a) the system is referred to as *SOCRATES*, an acronym for *System for Organizing Content to Review And Teach Educational Subjects* (Stolurow & Davis, 1965). Unlike the systems described and discussed to this point, SOCRATES represents a computer-controlled instructional system that is derived largely from earlier work with teaching machines and programmed instruction. Stolurow and Davis (1965) state that SOCRATES, "was developed as an adaptive teaching machine system" (p. 198). In spite of its origins, Stolurow realized that the constraints to program design and flexibility inherent in most electro-mechanical teaching machines were largely absent with computer-controlled devices. Stolurow and Davis (1965) observe that some computer-controlled instructional devices are either unsuccessful, or that they attain limited use because they are nothing more than expensive versions of teaching machines or methods of programmed instruction, "There is little point in using a computer to simulate a Skinner-type machine, a programed text, or even a 'Tutor Text'" (p. 198). Given this awareness, Stolurow adopted some aspects of teaching machines while devising a method of operation designed to take advantage of the flexibility and power of computers.

The system is centred around an IBM model 1620 digital computer containing core memory and a model 1710 multiplexer unit to enable several student terminals to be operated simultaneously (Stolurow, 1967a). Stolurow (1967b) distinguishes between two versions of the system. SOCRATES I consisted of the components already mentioned, and a card puncher/reader as the means of permanent storage of programs. In the second version, SOCRATES II, the punch cards were replaced by an IBM model 1311 hard disk with a capacity of 250 k Bytes (Stolurow, 1967b). The maximum number of terminals that may be connected to the system is not clear. Stolurow and Davis (1965) state that 14 terminals may be connected. Stolurow (1967a) states that the system can control 13 terminals. The terminals used may either be ones designed specifically for SOCRATES, or they can be branching-type teaching machines such as Crowder's AutoTutor modified to be controlled by computer (Stolurow & Davis, 1965). Garner (1966) reports that the SOCRATES terminals were, "modified versions of a standard video branching product" (p. 89). While none of the common branching-type electro-mechanical teaching machines used a CRT or video display, it seems from Garner's description as well as that of Stolurow (1967b) that the SOCRATES terminal is based on the design of the AutoTutor teaching machine (see Chapter VI). The common elements of the branching-type teaching machines and the SOCRATES terminals are that both types use a rear-projection film strip and both types possess 15 keys. This design permits the terminals to be used only for multiple-choice questions. Stolurow and Davis (1965) state that this type of terminal was selected primarily because of the technological difficulties in creating a video display terminal, like that used in PLATO I, that could present both text and graphic information. Stolurow and Davis (1965) also cite findings from studies showing that there is little difference to the user's learning and retention between selecting and constructing a response, suggesting that it is not detrimental to require multiple-choice responses exclusively. Stolurow and Davis (1965) contend that the differences between an electronic display such as a CRT terminal and a film-based terminal are minor in respect to pedagogical method, "the transformation accomplished by display is trivial, e.g., the linear motion of a piece of paper" (p. 195).

Stolurow (1967a) contends that the design of the SOCRATES terminal facilitates the rapid production of instructional materials, "prepared test material can be photographed and placed on the system very quickly" (p. 265). While it may take less time to prepare instructional material for SOCRATES than for other computer-controlled instructional systems such as PLATO, it is important to recall that Gilbert (1979) states that teaching machines using programs prepared hurriedly function like "mechanical page turners" (p. 15; see also Chapter VI). This condition is likely one that Stolurow desired to avoid, given the quote cited earlier about how computer controlled instructional devices should not mimic teaching machines. Although the technical nature of the SOCRATES terminals was considered a minor part of the system, the limitations imposed by the technology selected, constrained both the design and the flexibility of the system.

Instructional programming on SOCRATES was accomplished using either the FORTRAN language or the Symbolic Programing System, an alphanumeric code (Stolurow & Davis, 1965; Stolurow, 1967b). The code, used to facilitate the editing of programs, consists first of a four digit number representing the frame number of the film to be displayed on the terminal. A space separates this number from the rest of the code. The next item in the code is a letter, signifying the correct key on the terminal. If more than one correct response is permitted, then additional letters are listed, each followed by an asterisk. These letters are followed by other letters identifying additional response keys on the terminal. No asterisks are placed following these letters. This designation signifies incorrect responses. A zero placed after the last letter serves as a spacer. This is followed by one or more two digit numbers corresponding to the numbers of the letters representing correct responses. Each of these two-digit numbers represents a command to the computer to move the film the number of frames indicated by the number, when the corresponding key is pressed (Stolurow, 1967b).

Stolurow designed a special type of programming logic for SOCRATES, referred to variously as *idiomorphic programing* (Stolurow & Davis, 1965) or *idiographic programing* (Garner, 1966; Stolurow, 1967a; 1967b). The programming logic appears to be a hybridization of Pask's initial attempts at fuzzy logic and aspects of programmed instruction. Stolurow and Davis (1965) describe the essence of this programing logic as the entering of as much information about the student into the computer as possible. Such information may include personality descriptions, results of aptitude tests, results of achievement tests and pre-tests, a description of the subject matter to be learned by the student and the student's identification number (Stolurow, 1967a). This information is used by the computer to determine what material and questions will be presented. Stolurow (1967a) states that idiographic or idiomorphic programing, "was developed to provide a two-stage decision process: in the first stage the pre-tutorial decisions are made and in the second tutorial decisions" (p. 257).

Limitations of the terminals make one of the pre-tutorial decisions necessary. Each terminal contains a film strip of up to 1,500 frames, much like Crowder's AutoTutor teaching machine (Stolurow & Davis, 1965; see Chapter VI). Stolurow (1967a) states that the available instructional material is too voluminous to fit onto one film strip. In consequence, some material is available only at particular terminals. If a student tries to use a terminal that does not possess the necessary information in its film strip, then the first stage of the idiographic/idiomorphic program directs him/her to an appropriate available terminal. Instructional material is selected as the result of the second stage of idiomorphic/idiographic programming, based upon the personal information entered about the student (Stolurow, 1967a).

Besides recording whether a student response is correct or incorrect, the computer causes one of two lamps to be illuminated on the student's terminal. Illumination of the green lamp indicates that the response is correct, while a red lamp indicates that the selection is incorrect and that remedial information will be presented (Stolurow & Davis, 1965). Unlike branching-type teaching machines that decide upon what branch to take on the basis of the last question answered, SOCRATES can present information in varying degrees of difficulty based upon the analysis of several responses. If the initial questions in a remedial sequence are all answered correctly, for example, then the computer may either return the student to the main program or present additional remedial information that is more difficult (Stolurow, 1967a). Stolurow (1967a) also notes that the instructional strategy used may be changed according to criteria placed in the computer program. The computer may shift from an inductive to a deductive approach depending upon the responses and the aptitude of the student. In this manner, SOCRATES operates similarly to some of Pask's adaptive machines. It is important to note, however, that the variability of instructional material is limited by the individual frames of information available on the film strip. Stolurow (1967a) considered this limitation, since he notes that if the computer finds that the student is unable to meet any performance standard in the subject matter, then a message is typed at the instructor/programmer's terminal listing the name of the student, the nature of the problem and suggestions for appropriate remedial assistance.

SOCRATES seems to have remained largely an experimental system, since there are no indications that it was produced for commercial sale. Further development of the system was likely preëmpted because of technological developments such as inexpensive CRT displays and the demise of electro-mechanical teaching machines. While this collaborative effort between an educator and a computer company did not lead to the marketing of a viable computer-controlled instructional device, another venture met with much greater success.

IBM 1500 System

The IBM teaching machine projects mentioned in previous sections were not the only endeavors of that company into the realm of instructional devices. Another experimental project was started in 1961 both to facilitate the designing of course materials to be administered by computer and to assess the efficacy of such materials compared to traditional methods of instruction (Garner, 1966). Based at the IBM Research Center at Yorktown Heights, New York, the computer-controlled system consisted of a model 7010 computer that could operate up to 40 model 1050 teletype-like student terminals (Hartman, 1966). The terminals could be located at remote sites, connected to the central processor through ordinary telephone lines. Hartman (1966) notes that both an optional visual unit and an audio unit, controlled by computer, could also be connected to each terminal. The visual unit consists of a modified slide projector with a capacity of 80 images and a maximum seek time less than four seconds. The audio unit is modified tape recorder that, by means of a track encoded with digital information, can access discrete messages at a speed 20 times that of normal playback (Hartman, 1966). Besides being able to present pictorial and aural information, the experimental system was modified to facilitate the creation of course material by individuals ignorant of computer programming languages. An authoring language called *COURSEWRITER* was developed by 1964 (Hartman, 1966; IBM Announces, 1966). The Coursewriter language uses a series of operational codes. These two character mnemonic representations signify instructional-like operations to the programmer, but represent more elaborate commands to the computer. If one desires to place an existing macro program into the main program, for example, then the operational code *cm* is entered followed by any parameters that the programmer wants the computer to conform to. This code causes the computer interpreter to place the called macro program into the main program at that point. In using the coursewriter language, a programmer is required to possess knowledge of the instructional-like operations of the computer software only instead of having to know an abstract computer language as well. The purpose of the COURSEWRITER language is similar to the TUTOR language developed for PLATO, mentioned in a previous section. Although COURSEWRITER and TUTOR are related more to the process of instruction than most programming languages, these authoring languages are considered to be low-level, nevertheless, since the author must first learn the significance of mnemonics or single-word commands to use the languages effectively.

Through the addition of visual and aural elements, plus the development of an authoring language, IBM created a functional but experimental computer-controlled instructional system. The commercial success of systems such as PLATO, which were designed either by university personnel or through collaborative ventures between companies and universities, likely induced IBM to develop a commercial version of their computer-controlled instructional system in conjunction with university personnel. IBM collaborated with individuals at Stanford University beginning in 1964 (Atkinson, 1968; Atkinson & Wilson, 1969). A likely reason for the selection of these individuals was that Stanford already possessed a functional experimental computer-controlled instructional system. Atkinson and Wilson (1969) report that this system was begun in 1963 and it was composed of components from a diversity of manufacturers, "Since there were no integrated computer-assisted instruction systems available at that time" (p. 5). While this statement is correct as far as commercially-produced systems are concerned, it is important to recall that the PLATO system produced by the University of Illinois was already functional.

The Stanford system was based initially on a Digital Equipment Corporation model PDP-1 computer. An IBM model 7090 disk drive provided storage. Up to six terminals could be controlled by the PDP-1 in this system. Each terminal consisted of a Philco CRT display with a light pen, an IBM image projector that uses slides and a Westinghouse random access audio player (Atkinson & Wilson, 1969). The system was tested by bringing in local elementary school children. Atkinson and Wilson (1969) report that lessons were developed in the subjects of mathematics and language arts. The apparent success of this system resulted in the United States Office of Education presenting a large grant to Richard Atkinson and Patrick Suppes in 1964, for the development of computer-based programs in reading and mathematics (Atkinson, 1968). Atkinson (1968) notes that because of research interests, he developed courseware in reading while Suppes developed mathematics courseware. In conjunction with the awarding of the grant, IBM entered into an agreement with Atkinson and Suppes for the development of a prototype computer-controlled instructional device designed to be marketed commercially (Atkinson, 1968). The commercial system devised through this collaborative effort was named the *IBM 1500 system*.

The prototype 1500 system used an IBM model 1800 computer as the central processor (Atkinson & Wilson, 1969). Storage consisted of a single model 2402 tape unit and 6 model 2310 disk drives (International Business Machines, 1966). A model 1443 line printer enabled the system to provide printed output of program code and entered information. Program entry was accomplished either through using punch cards or by keyboard. A model 1442 card reader/puncher was supplied with the system for this purpose.

In keeping with the design of the initial Stanford system, IBM designed a student terminal that contained a CRT display and a light pen. According to Atkinson (1968) the light pen was included because, "we have not as yet addressed ourselves to the problem of teaching first-grade children to handle a typewriter keyboard" (p. 227). In other words, it is contended that pointing is a more natural activity than pressing keys marked with abstract symbols. From the previous quote it appears that Atkinson (1968) was either unaware of, or he chose to ignore the theoretical bases and practical work undertaken by Moore with the Talking Typewriter.

IBM included a standard or qwerty keyboard as a fixed part of each terminal. While the terminal was designated as the *1510 Instructional Display*, it could be used only to present textual information as well as simple line drawings. Neither the display or the central processor had the capability to generate half-tones or other complex graphics. To address this limitation, IBM designed a new image projector based initially on the experimental version it had developed previously.

Slides were not used in this projector, probably because of the small capacity of most slide projection systems. The new apparatus, designated as the *IBM 1512 Image Projec-*

tor, consists of a housing similar to that used for the CRT display. The projector housing contains a rear projection screen, a projector lamp, mirrors, computer-controlled shutters and a drive system designed to move specially prepared 16 mm motion picture film. Each reel of film, designed to be self-threading once installed in the housing, could contain up to 1,024 black and white and/or colour images (Atkinson & Wilson, 1969).

Awareness of each image address by the CPU is facilitated by a digital code comprised of clear areas and one or more small black squares located in the area of the film used normally for the sound track. By means of this index code and 10 photocells inside the projector, the CPU can control the image projector so that it displays particular images both quickly and accurately. The prototype version of the 1500 system, by means of a specially designed multiplexer and a separate unit designated as the *1501 Station Control*, could operate up to 16 student stations simultaneously, each consisting of an instructional display and an image projector (Atkinson, 1968). Atkinson (1968) states that the operational speed of the multiplexer is sufficiently rapid, "that from a student's viewpoint it appears that he is getting immediate attention from the computer whenever he inputs a response" (p. 227). This is an important feature in respect to instruction designed to follow the tenets of Skinnerian behaviorism.

The station control unit also contains a hard disk with multiple read/write heads for recycling the images on each CRT, referred to as the video buffer, as well as circuitry for interpreting signals from the light pens (International Business Machines, 1968). The read/write heads for the video buffer were supplied in groups of eight, and it was possible to add head groups until the maximum of 32 heads was reached. With this arrangement it was possible for a small system to possess only eight heads with provision for expansion. Initial cost and maintenance of the video buffer could be kept to a minimum, therefore.

In the prototype version of the 1500 system, aural information was provided by a large stand-alone unit referred to as the *1505 Audio Adapter* (International Business Machines, 1968). The audio adapter, intended to be located near the central processor, could be equipped with up to eight separate tape drives, each designed to play tape cartridges with a maximum capacity of two hours. Individual messages, however, are limited to a maximum of five minutes. Each tape is recorded with four tracks, each track capable of holding up to 40 minutes of information. Three tracks could be used either for recording information to be presented to users, or they could be used to permit users to record responses and comments for subsequent review by an instructor. One track is reserved for a digital code which permits the computer to control the position of the tape in a manner similar to the way the film in the image projector is controlled. Atkinson (1968) notes that with this arrangement it is possible to synchronize an indicator on the CRT with printed words on the screen and the corresponding spoken words, "much like the 'bouncing ball' in a singing cartoon" (p. 226). The use of such visual cues not only serves to capture and sustain the interest of the user, but this particular arrangement also encourages the formation of associations between the sounds of the words and their written symbols. Aural information is delivered to the student usually through a headset equipped with an attached microphone, but specialized devices may be used instead.

Although the 1505 audio adapter used with the prototype was intended to be a component of the commercial version (International Business Machines, 1966) the 1505 was superseded by individual self-loading reel-to-reel tape drives located at each student station. While no reason is given to explain why a centrally-located audio system was abandoned in favour of individual machines, it seems that the design of the centrally-located unit could diminish the pedagogical efficacy of the system. Using the 1505 unit, it is possible for only one station at a time to gain access to a particular point on a given tape. In such situations, one station must wait until another is finished with that portion of the tape. It is probable that the delay caused by waiting was considered excessive and, therefore, detrimental in respect to the prevalent theories of reinforcement and feedback at that time; reaction to student input must be immediate. There is support for this contention in an IBM publication describing the new individual tape drives, "A separate prerecorded tape cartridge is used at each instructional station. This permits each student to hear messages associated with the particular course he is taking and at the appropriate time in his instructional program" (International Business Machines, 1969, p. 1).

The individual tape drives used to supersede the 1505 unit are referred to as *1506 Audio Units* (International Business Machines, 1968). Each unit consists of a housing containing the playback and recording mechanism, provision for the loading of tape reels and a jack for the connection of combination head phones and microphone, or for the connection of specialized audio output devices. The recording medium is 0.25 inch (6.4 mm) wide magnetic tape connected to a special leader and trailer, and wound onto a 5 inch (127 mm) diameter reel of a design unique to this machine. Each reel can hold up to 600 feet (182,880 mm) of tape (International Business Machines, 1968). Using the maximum length of tape, each reel can hold up to 2 hours and 40 minutes of information in message blocks lasting from a minimum of 0.5 seconds to a maximum of slightly less than 5 minutes (International Business Machines, 1969). The capacity of the tapes was estimated to be sufficient for most purposes. It is important to note that some courses, such as the CARE course from Pennsylvania State University, required several reels to hold all the required information.

The operation of the 1506 audio units is similar to that of the larger 1505, where each tape contains four tracks, three consisting information and one containing address data. Preparation of instructional tapes could be undertaken from an instructional station, since each audio unit is connected through the multiplexer to the station control unit. Once a master tape was completed, additional copies could be prepared with special tape duplicating equipment (Cowper & Romaniuk, 1975). While the original station control unit was designated model 1501, a unit modified through the addition of circuitry and designated model *1502* was required to operate the 1506 audio units (International Business Machines, 1969). The 1506 audio unit may function in any one of three modes at a particular time. In most instances the unit operates in *terminal mode*, where it is under the control of the CPU and the user is able to record information only when the courseware permits it. In *sector address mode* the unit may be used to record the address track by the computer, a process referred to as *initializing* (International Business Machines, 1969). *Assembly mode* enables a course author to record aural information, both from a microphone and from ancillary production equipment. Figure 84 (Division of Educational Research Services, University of Alberta) illustrates the components of a typical student terminal of an IBM 1500 instructional system. The photograph was taken of the system installed at the University of Alberta.

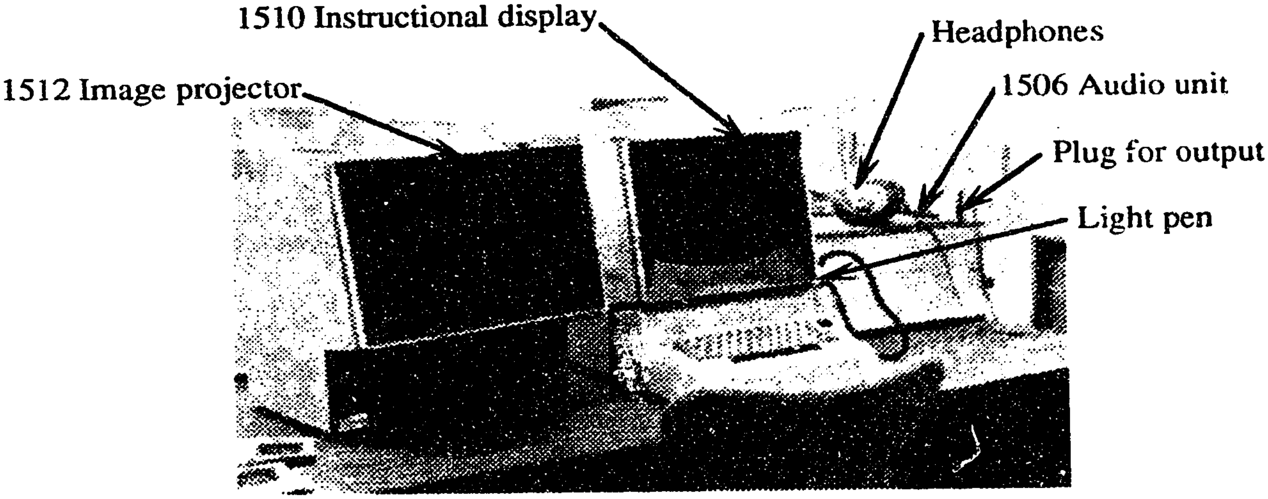


Figure 84. Components comprising a typical student terminal of an IBM 1500 system

While the 1500 was designed to be an automatic instructional system, IBM considered it necessary to have an individual oversee the operation of it at times when in use by students. IBM states that this individual, called a *proctor*, "should understand the operating system [of the 1500] and its procedures, the instructional system, and should be familiar with the course material he administers" (International Business Machines, 1968, p. 3). The duties of the proctor include managing student registration on the system, assisting students with difficulties and attempting the rectification of operational problems. Without suitable instruction, the ordinary classroom teacher is likely unable to address courseware and/or system problems. The proctor could make changes to courseware and to the operation of the system at a special terminal, or at any 1510 Instructional Display by entering the correct password and commands. The proctor terminal, designated as a model *1518 typewriter*, is actually an IBM model 735 selectric typewriter modified to use fan-fold paper and to be connected to the 1500 system. The prototype system was equipped with two such terminals (International Business Machines, 1966).

A new version of IBM's Coursewriter authoring language, referred to as COURSEWRITER II, was developed concurrently with the 1500 system (*IBM Announces*, 1966). Coursewriter II, like the first version, is intended to facilitate programming by individuals without extensive background in or knowledge of computing. This feature was considered important by IBM in encouraging educators to use computer-controlled instructional devices. The importance of authoring languages was appreciated by other concerns engaged in the design and marketing of computer-controlled instructional devices intended for educators. It should be recalled from a previous section that the TUTOR authoring language was devised for PLATO. Production models of the 1500 system were also delivered with the calculating and programming language *APL* (A Programming Language, devised by Iverson, 1966) known as Mathematical Algorithm Translator or *MAT*, modified specifically for the system (Gleason, 1967; Hunka & Romaniuk, 1974). With MAT, the 1500 system could be used not only for designing and presenting instructional material, but could also be used for complex calculations such as those for statistical analyses. Entry and editing of course material could be accomplished using a terminal, either instructional or proctor, or by using punch cards (Cowper & Romaniuk, 1975). Each method possesses advantages over the other. Spelling and syntax errors may be corrected easily on an interactive terminal, a difficult process with punch cards, since a new card must be punched for every change made. An interactive terminal also precludes the need to assemble the program before the code can be tested. By using punch cards, however, the author is able to prepare course materials at locations away from the 1500 system and at times of his/her choice. An interactive terminal requires the author to be present at that location and at times convenient to the schedule of the system (Cowper & Romaniuk, 1975).

In early 1966, before the prototype 1500 was operational, IBM announced the system and they endeavored to obtain agreements to sell or rent 1500 systems to as many educational institutions as possible (*IBM Announces*, 1966). In June 1966, for example, the University of Alberta entered into agreement with IBM for the rental of a 1500 system (Agreement for IBM Machine Service with the University of Alberta, June 27, 1966). The actual system hardware did not arrive on campus until 1968.

In conjunction with Stanford University, the prototype 1500 system was installed in the Brentwood elementary school in East Palo Alto, California, in July 1966. Under the direction of Patrick Suppes, the prototype was used to instruct aspects of reading and mathematics (International Business Machines, 1966). While the prototype functioned as anticipated, it was discovered that a CPU of greater capacity and speed could enhance the operation of the system. In most production models of the 1500, a model 1131 CPU was used instead of the smaller capacity and slower speed model 1800, although the system could be ordered with the model 1800 (International Business Machines, 1966). Three models of the 1131 CPU were available. Each model was also available in a number of versions. Models 1 and 2 possess a core storage cycle time of 3.6 microseconds, while model 3 possesses a 2.2 microsecond cycle time (International Business Machines, 1967). The versions of each model refer to the size of the core storage in kilobytes. An 1131 designated as model 3C, for example, possesses a 2.2 microsecond cycle time with a core capacity of 16 k Bytes. The variation in core size and cycle speed were intended to permit the 1500 system to be customized to particular installations to keep the delay between the entry of data and computer response to a minimum. A system possessing a high number of student terminals would likely use a CPU with a faster cycle time, since more terminals require a faster switching time to minimize response delays.

Like the CPU, a choice of terminal displays were available. Instead of the CRT-based 1510 instructional display, the system could be ordered with the model 1518 modified typewriter. While it might appear that using typewriter terminals would reduce the cost of the system, since no CRTs or video buffers are required, any reduction in cost is offset by the major disadvantage of typewriter terminals. They cannot print or accept input as fast as CRT based displays (International Business Machines, 1968). The slow speed of the typewriter terminals also slows down the functioning of the CPU, since there is no buffer between the terminals and the CPU. In consequence, the CPU is not available to other terminals until the operation being carried out on the first terminal is completed. The extra time required for the typewriter terminals might prove costly both in instructional time and in the ability of the system to sustain the attention of some users. It appears that most institutions using 1500 systems selected versions of the 1131 CPU and chose the 1510 Instructional Displays. Figure 85 (after illustration and photographs from Division of Educational Research Services, University of Alberta) is a schematic diagram showing the major components of a 1500 system. This diagram represents the original configuration of the 1500 system installed at the University of Alberta.

Dimmick (1977) claims that the first production 1500 system was obtained by and installed at the Pennsylvania State University in December 1967. The original configuration consisted of an 1131 CPU, disk and tape storage, a multiplexer, a model 1502 station control unit and eight student stations. Each station consisted of a model 1510 instructional display, a model 1512 image projector and a model 1506 audio unit (Dimmick, 1977). This system was later expanded to 32 student stations, the maximum possible. The Pennsylvania State University was able to obtain additional 1500 systems, through the provision of funds from organizations outside the university, such as the United States Office of Education.

Three additional systems were acquired from IBM beginning in 1970. Dimmick (1977) states that these were installed in truck-hauled vans modified so that the systems could be transported to locations throughout the state, "to make courses available to as many inservice professionals as possible" (p. 33). The vans were modified so that the sides could be expanded when the vans were parked. In this way the vans themselves were used as schools. This arrangement meant that the time required for setting the system up was minimized. As well, instruction could be provided without disrupting classes at local schools and the system could also be used at times such as weekends and evenings when most schools were closed. Each van remained at a location normally from between six to eight weeks, usually next to a school where there was space and power for the van. Up to 250 students could be served during each visit by a portable system. The first portable system contained 15 student stations, while the latter two systems each contained 16 stations (Dimmick, 1977). A large number of courses covering several subjects were written for the four 1500 systems of the Pennsylvania State University. Subjects addressed include: music, shorthand, elementary math, fortran, physics, some medical simulations, spelling, psychology, the metric system, and identification of learning handicaps (Dimmick, 1977).

It appears that IBM envisaged considerable manufacture of 1500 systems. Gleason (1967) states that prior to the installation of any production models, IBM anticipated leases and/or sales to 40 educational institutions. As with some instructional devices

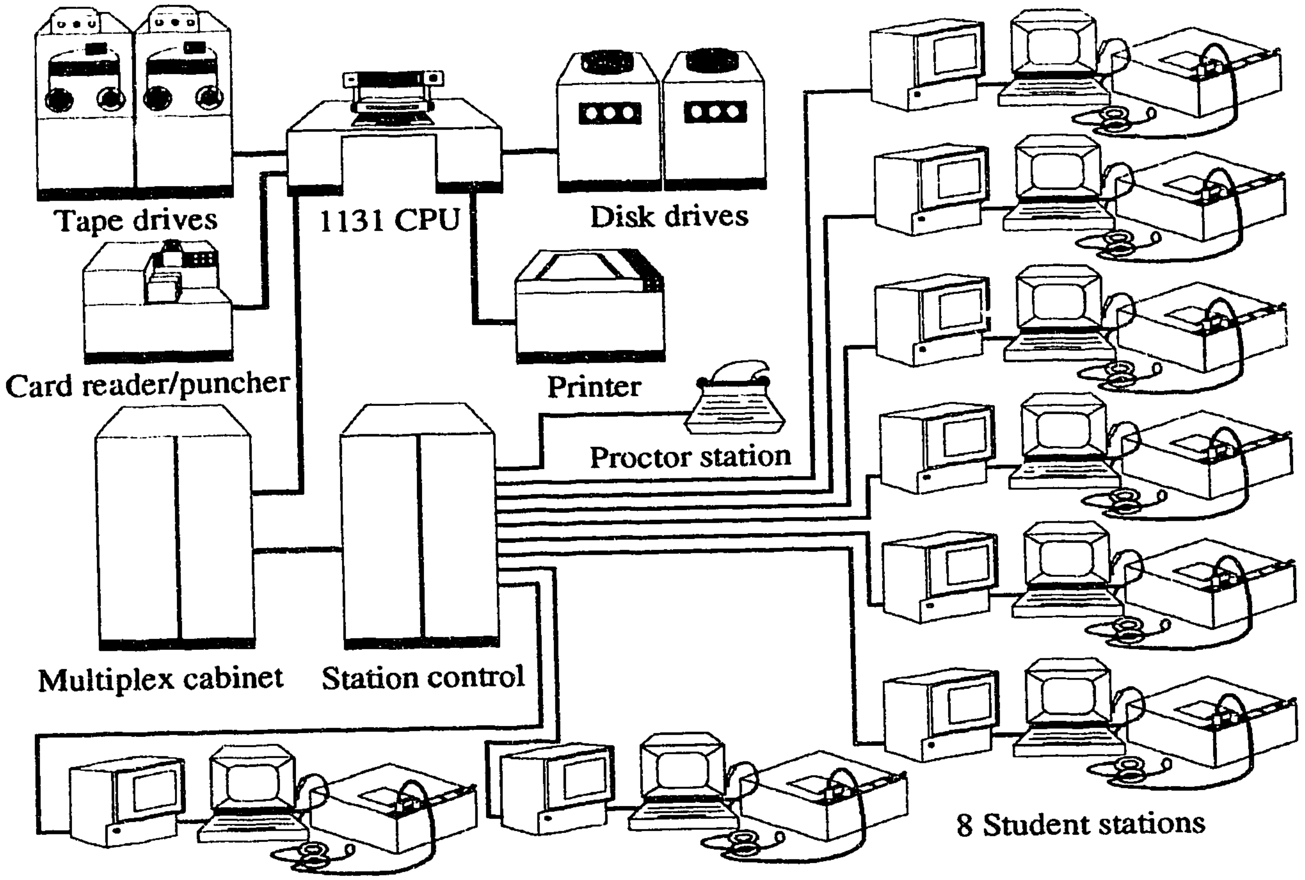


Figure 85. Diagram showing the main components of an IBM 1500 system

described in previous sections and chapters, actual interest in the 1500 system fell short of expectations. Holland and Hawkins (1972) state that 1500 systems were installed, "in about 20 centers, most of them at higher educational institutions" (p. 329). Centres include: Stanford University; Science Research Associates, a company that had manufactured punch boards and which was owned by IBM; Thomas J. Watson Research Center, IBM; Pennsylvania State University, four systems; Florida State University; University of Connecticut; Texas A & M University; University of Illinois, Chicago Circle campus; Rochester Institute of Technology; State University of New York, Stony Brook; United States Navy at San Diego, California; United States Army at Fort Monmouth, New Jersey; Montgomery County Schools, Virginia; Golidette School, Washington, D.C.; Québec Ministry of Education; and the University of Alberta (personal communication with Dr. S. M. Hunka, July 1991). While it appears that 19 systems were in use, it is important to note that some installations were short-lived, and it is likely that machines removed from one location were later used in another. The system installed at Québec, for example, was in use for approximately one year, so it is likely that the entire system or components of it were used to augment existing systems, or were used in new installations (personal communications with Dr. S. M. Hunka, July 1991).

One of the longest-lived installations was at the University of Alberta. Housed in the Division of Educational Research Services under the directorship of Stephen Hunka, the initial configuration consisted of: an 1131 CPU, model 2D (3.2 microsecond cycle time with core capacity of 32k Bytes); an 1133 multiplexer; a 1442 card reader/puncher; an

1132 line printer; disk storage; a 1502 station control unit; 8 student stations each containing a 1510 instructional display, a 1512 image projector and a 1506 audio unit; and a 1518 typewriter proctor terminal (International Business Machines Agreement for IBM Machine Service, 1968; Hunka & Romaniuk, 1974; see also Figure 85). The system was expanded ultimately to 21 instructional displays, 19 image projectors, 20 audio units, two proctor terminals, tape drives and new disk drives (Hunka & Romaniuk, 1974). Some of the components used to expand the system were obtained from 1500 systems withdrawn from use at Pennsylvania State University (Letter to S. Hunka from F. Dimmick, February 14, 1977).

The 1500 system at the University of Alberta was used to instruct courses in a wide range of subjects. Courseware developed locally as well as programs developed on other 1500 systems were made available. Courses developed locally include: statistics; arithmetic instruction and drill; instruction in spelling and drill exercises; introduction to the COURSEWRITER II language and its use; introduction to APL and its use; fundamentals of data processing; introduction to reading and writing French; optics for first-year university physics students, a program using drawn simulations of instruments; pre-calculus mathematics; essentials of cardiology, which uses a specialized headphone set resembling a stethoscope; basics of immunization, including a simulation on the correct procedure for inserting hypodermic needles; simulated cases for the training of midwives; and introduction to machine tools (Hunka & Romaniuk, 1974). Examples of courseware developed at other installations include: introduction to electrical and electronic theory, developed at the U. S. Army's installation at Fort Monmouth, New Jersey; CARE I and CARE 4 programs, developed at the Pennsylvania State University, to instruct teachers on the identification and accommodation of students with handicaps that are usually difficult to detect. At least one operational modification was adopted from other installations. One example is known as the *Penn State Patch.* This addition to the operating system enables a student either to enter a particular key sequence or to point to a specific area of the screen with a light pen to access special ancillary features such as a calculator or a glossary. These items are intended to be useful adjuncts to the lesson or course running at the time (Cowper & Romaniuk, 1975).

Hardware modifications were also made to the University of Alberta's 1500 system. Hunka and Romaniuk (1974) note that a commercially-produced reward dispenser was connected to one student terminal as part of an experimental program designed to facilitate learning in students possessing particular mental disabilities. The device distributed a single M & M candy to the student following the correct response to a question or series of questions. While the pedagogical merits of this behavioristic approach may be questioned (see Chapter VI) the use of the reward dispenser exemplifies the flexibility of the 1500 system in presenting instruction according to different theories of learning. In conjunction with IBM, a focusing knob and mechanism were devised and added to the image projectors to compensate for blurry images caused by buckling of the film as the projection lamp heated it. System efficiency was improved by the addition of two magnetic tape drives in 1971 and the replacement of the original model 2310 disk drives with faster model 2311 drives in 1973 (Hunka & Romaniuk, 1974). The addition of faster disk drives increased the efficiency of the system further by decreasing delays in gaining access to particular courses.

While it may seem that most of the computer-controlled instructional devices discussed to this point were used primarily to present instructional materials as adjuncts to teacher-based instruction, the University of Alberta's 1500 system was used as the primary source of instruction in some instances. Some of the courses, therefore, were extensive and required the student to spend considerable time to complete them. The cardiology course was estimated to require 24 hours, the electronics course required from between 40 to 50 hours, while the statistics course required about 70 hours (Hunka & Romaniuk, 1974; Hunka, 1977). While the goal of many designers of instructional devices was to develop a device or system that could be the primary presenter of information, the attainment of this goal introduced new pedagogical problems. The range of pedagogical and administrative problems facing a course author or designer using the 1500 system usually transcend those faced by most individual classroom teachers.

Before an extensive course could be designed for the system, curriculum design had to be addressed. In some instances, the author or designer must ensure that the content is faithful to the approved curriculum before the course is implemented, since extensive changes to a program are difficult to make, especially when students are proceeding through it on an individual basis. Apart from disrupting students using the course, changes to existing programs require much time. Cowper and Romaniuk (1975) state that, "authors spend an average of 80-100 hours to produce one hour of student course work" (p. 7). Related closely to curriculum design is consideration of the practical, psychological and theoretical aspects of instructional design. While the intent of most courses is to present germane information in a clear and concise manner, the transformation of the theoretical into effective practice is a perpetual problem of the teacher. This problem is amplified by a computer, since most computer-controlled instructional systems cannot ascertain immediately when a particular teaching strategy is not working, and most such systems cannot substitute other strategies quickly, the way many human teachers do. This condition forces the author of a course to examine and to evaluate his/her personal method of teaching. Rossall (The computer, 1972) states that this development, "is not a very comfortable process for the lecturer, but it is undoubtedly beneficial [to the learner]" (p. 17).

It should be recalled from Chapter VI, that B. F. Skinner and other individuals contend that designing instruction according to a single improved theory of learning, namely behaviorism, enables teaching machines to provide instruction better than most classroom teachers. While the expectations of the theory were high, its practical efficacy was deemed unsatisfactory by many teachers. Hunka (1977) contends that the apparent wide disparity between the expected success of particular theories of learning and their actual practical efficacy results because many individuals who devise such theories do not consider the practical problems of pedagogy, "Too many specialists have become fixated at the level of Piagetian categorizations [or other theoretical considerations], and have forgotten about the problems faced daily by the practicing teachers" (p. 7). It is the evaluation of practical application, therefore, that reveals to the teacher whether or not a particular theory of learning is effective. A fixation on using one particular theory of learning exclusively may also result, in the case of instruction by computer, in the material being presented in a boring fashion, much like the *mechanical page turning* criticism leveled against teaching machines (see Chapter VI). To design an appropriate, motivating and attention-sustaining course for delivery by computer, therefore, requires consideration of learning theories in conjunction with practical methods of teaching. Moreover, consideration must be given to the extent illustrative and/or aural materials should be used.

Although the 1500 system possessed the ability to present a variety of visual and aural materials, these capabilities should not induce the course designer or author to employ such materials indiscriminately. Although several instances are noted in previous chapters where illustrative materials facilitate learning, it is possible to use such material to excess, so that they interfere with the learning of the intended material. Elements of the various presentation media must also be used carefully. Colour, for example, is a necessary element in a reproduction of a microscope slide showing a stained tissue sample. Using colour in a textual sequence to emphasize important words or passages, however, may distract or confuse the student.

Practical problems of a more general nature must be considered as well. Sustaining student attention and motivation are two perennial problems faced by teachers. These problems are especially difficult for a computer-controlled instructional device to contend with. It is preferable for the author or course designer to anticipate these problems instead. Some attention and motivational problems may be avoided by designing materials appropriate to the age group for which the course is intended. The provision of praise or tangible rewards may be appropriate in some instances, but the caveat of overuse remains applicable. With some motivational techniques, such as providing a tangible reward, the author or course designer is returned to the consideration of theory.

Evaluation techniques must also be considered. Not only is the author compelled to select or design a particular method of evaluation, but the instructional system must be able to administer it. Particular methods of evaluation may be more appropriate than others given theoretical and practical considerations. In the cardiology program, for example, multiple-choice examinations were selected that presented symptoms reported by a patient as well as aural information to the student's stethoscope. While computer-administered multiple-choice examinations may be criticized because the student usually does not have the option of altering a response once a question is answered, this condition reflects reality in cardiological diagnosis, since few cardiologists are afforded either the time or opportunity to reassess a diagnosis (The computer, 1972).

Appropriate methods of recording student progress through a lesson and results obtained on examinations are also major considerations and problems. When a student decides to quit working on a lesson at a particular point, does the system return the student to that point the next time he/she returns to work, or does the system place the student at an earlier point in the lesson, a point considered to be a *logical* stopping place? While returning a student to a logical stopping point may seem sound pedagogically, doing so may irritate the student who recalls the information well and who wishes to proceed. In such instances, the student may become frustrated since the so-called individualized instructional system has constrained the degree of individualization. A record of each student's progress that is easy to interpret is also necessary if the author or course designer is to ascertain if there are common problem areas in a lesson or course.

Consideration must also be given to the time required for the course, since it is unlikely that only one course will be offered or only one class will use the system. If, for example, it is known that the system is already booked for four hours every school day, then it is unlikely that many students in another class will be able to complete a course on the system requiring three hours daily, when available time is two hours per day.

In spite of the practical and theoretical problems faced by authors designing courses for computer-controlled instructional systems, there are pedagogical advantages in using such systems instead of a live teacher. Some computer-controlled instructional systems permit the student to progress through the material at entirely his/her own rate. The management of this form of individualized instruction is handled easily by a computer, not a feat accomplished easily either by most live teachers or by electro-mechanical teaching machines. Hunka (The computer, 1972) notes that the seemingly impersonal nature of a computer may actually be a positive attribute, since the computer system, "doesn't play favourites, or have personal prejudices, nor does it have the ability or desire to crush a student in front of the entire class" (p. 20).

While several 1500 installations were used to teach materials in a variety of subject areas successfully, IBM announced in 1977, its intention of withdrawing its support of the system in 1979 (Letter from R. Hunter to S. Hunka, April 27, 1977). By the time of this announcement, however, several 1500 systems had already been decommissioned including some of the largest. In 1976, preparations were made for the termination of the mobile and fixed 1500 systems at the Pennsylvania State University by the end of June 1977 (Dimmick, 1977). Financial considerations comprised the main reasons for suppressing this installation. Dimmick (1977) states, "increased costs of various programs throughout the University system, along with reductions in aid from both the state and federal levels have forced the University's administration to evaluate programs and redistribute efforts" (Letter to S. Hunka, February 14, 1977). Elsewhere, Dimmick (1977) states,

> Too often, school and university administrators are not able to see past the initial investments for the computing system and the curriculum. It is indeed true that these first costs are more often than not prohibitive for a school district or economically-bound university, however it is the utilization over a period of time, which makes CBE [Computer Based Education] a sound investment. (p. 17)

While cost was a major factor limiting both the deployment and the continued use of many 1500 systems, other factors also contributed. It is noted in previous paragraphs and sections that considerable time is required to produce each hour of instruction presented by machine. It appears that in some instances, universities and other educational institutions did not encourage individuals to prepare course materials. Hunka (The computer, 1972) states,

> Why should a professor put in hundreds of hours preparing his material for computer programming when he receives absolutely no rewards for his efforts, yet if he writes a text he not only gets 'brownie' points towards promotion and tenure, he also gets royalties from his books. (p. 19)

Apart from a lack of incentive, Hunka (The computer, 1972) also notes that many educational institutions spend little time and money on the evaluation and development of instructional techniques. When such institutions place a low value on the development of instructional devices and methods of instruction, then it is unlikely that most faculty or staff will show much interest either. While some institutions and individuals did consider using computer-controlled instructional devices, the expectations of the devices were sometimes greater than their capabilities. Hunka (1977) notes that some educators, "thought that one could simply plug the computer into a power source, and presto, instant education! The computer was expected to accommodate the gifted, the slow, the ghetto child, as well as the average classroom child" (p. 2).

The obsolescence of hardware also contributed to the demise of the system. While some principles of design embodied in the 1500 system were ahead of their time, the advent of smaller computers possessing a larger memory capacity and which operate faster for less cost, meant that the 1500 system would not be economical to continue. In spite of the availability of smaller and faster computers, by the time that the University of Alberta's 1500 system was terminated in 1980, none were capable of interpreting the coursewriter language and presenting the courses. While some institutions addressed this problem by re-writing courses for other computers and computer systems, other institutions discontinued much of this work, since no compatible system was available.

Stanford's Digital system

While IBM and Stanford University were collaborating on the 1500 system, the original Stanford computer-controlled system was also being developed (Atkinson & Wilson, 1969). The capacity of the original system was augmented and its purpose altered by the addition of three more Digital Equipment Corporation computers (Suppes & Jerman, 1969). Two model PDP-8 computers were obtained to control communications with teletype terminals located at remote sites. These two computers possessed core memories of different sizes. The third computer, a PDP-10, was connected to the original CPU. The PDP-10 controlled disk storage and had provision for controlling a reproducer of digitized sound such as recordings of verbal instructions (Suppes & Jerman, 1969). The PDP-10 also shared some core memory with the original PDP-1, which continued to control the visual terminals. A memory drum was added to the PDP-1 to provide high-speed bulk storage for the system (Atkinson & Wilson, 1969). While most of the processing hardware was located at Stanford, one of the PDP-8 computers was located at a remote site in Morehead, Kentucky which controlled an array of teletype terminals.

This computer was connected to the main processor at Stanford through dedicated telephone lines. Telephone lines were also used to connect remote teletype terminal sites to the Stanford system. When complete, the system controlled 221 remote terminals (Suppes & Jerman, 1969).

While the system continued to be used for instruction in mathematics, some of the teletype terminals, designated as model 35, were equipped with Cyrillic keyboards. These terminals were used to instruct lessons in Russian. Apart from delivering lessons that present information and require responses from the student, the system could also provide drill and practice in subjects usually taught by a regular classroom teacher. In this manner, the system functions more as an adjunct or teaching aid rather than the primary means of instruction. Functioning in this manner, the system is known as the *Stanford drill and practice system* (Atkinson & Wilson, 1969). Atkinson and Wilson (1969) state that the,

> basic assumption in the drill-and-practice mode is that concepts are presented and developed by the teacher in the classroom, and the computer system furnishes intensified drill and practice on those previously developed concepts at a level of difficulty appropriate to each student. (p. 7)

Suppes and Jerman (1969) anticipated the future use of a digital audio unit that would reproduce verbal instructions for each student, the information being provided through headphones located at each terminal.

Atkinson & Wilson (1969) note that the Stanford Digital system is simpler both in hardware and in operation than the IBM 1500 system. Besides being unable to control complex terminals like those used with the 1500 system, or those used with PLATO, the software design of the Stanford Digital system could not enable real-time branching at student terminals (Atkinson & Wilson, 1969). Branching selections were made after the student quit work on a lesson. During the night, or at other times of low activity, the computer evaluates the progress of each student and on this basis determines what lesson or sequence of questions will be presented to the student next (Atkinson & Wilson, 1969).

Although Stanford's Digital system evolved from its initial configuration, it was technologically obsolete by the time it was augmented, and it was not marketed (Suppes & Macken, 1978). The inability to provide an interactive visual display was a likely reason why development was not continued, since both the 1500 system and PLATO possessed these features. The use of Stanford's system as a drill and practice teaching aid is likely another reason for its demise, since the expense of the system would be hard to justify given that a classroom teacher was also required to provide instruction. Attempting to capitalize on a seemingly lucrative market, some commercial enterprises developed and marketed computer-controlled instructional systems similar to IBM's 1500 system.

RCA Instructional 70 system

A further impetus encouraging development of other computer-controlled instructional systems was the contention common during the late 1960s, that there would soon be such an increase of students that there would be an insufficient number of teachers. This opinion likely motivated the Radio Corporation of America (RCA) to design a competing system to IBM's 1500 system, beginning in 1967, since that company states, "RCA Instructional Systems is developing a computer-based instruction (CBI) system to help teachers in their effort to provide individual instruction to an increasing number of students" (RCA Instructional Systems, 1968b, p. iii). Called *Instructional 70*, the system was intended to be used in schools and educational institutions at all levels (RCA Instructional Systems, 1967a). RCA Instructional Systems (1968b) notes that the instructional strategy of their computer-controlled system, "was developed by curriculum experts at

Stanford University, and adapted for use on RCA computers by the L.W. Singer Company" (p. 1-1). It is not surprising, therefore, that RCA's system is similar to IBM's 1500 system in several respects. Like the 1500 system, a low-level authoring language was developed for the RCA system. The language, known as *Instructional Language-1* or *ISL-1*, uses single letters, words, mathematical operands and punctuation characters to create a program in a manner similar to IBM's COURSEWRITER II language (RCA Instructional Systems, 1967b).

The hardware design of Instructional 70 was also similar to the IBM 1500 system. As well as being based on a mainframe computer that could operate a number of student terminals independently of each other, RCA planned to use CRT-based terminals that also could provide audio information (RCA Instructional Systems, 1967a). Although a reason is not provided, RCA did not offer a CRT-based terminal with the production model of its system, available by the end of 1968 (RCA Instructional Systems, 1968a).

An RCA Spectra 70/45G model mainframe computer containing a magnetic core memory of 262 k Bytes comprised the CPU. Six magnetic tape units and two disk drives comprised system storage. A supplied card reader-puncher provided one method of input and output, and a line printer was used for printed output. Through the use of multiplexing units referred to as model *680 line concentrators*, up to 192 student terminals could be connected to the CPU (RCA Instructional Systems, 1967a). Each line concentrator unit could control up to 48 student terminals. The line concentrator units also functioned as buffers for the individual terminals, holding information from the CPU until it could be printed by the terminal. System wiring could be used to connect line concentrators to the CPU when terminal installations were located less than 2,000 feet (610 m) away. Line concentrators located at more remote sites were connected to the CPU through ordinary telephone lines. Communication between the CPU and the line concentrators occurred at speeds between 2,000 and 2,400 bits per second (bps, also referred to as baud) depending upon line conditions, while the communication speed between the line concentrators and the student terminals was only 110 bps, since the terminals could not send or receive data at higher speeds (RCA Instructional Systems, 1967a). Given these speeds of data transmission, the student terminals were slow and they likely lagged behind the reading speed of many students.

The terminals, designated as model *733 Student Instructional Terminal*, consisted of a teletype-like device equipped with a function switch located beneath a lockable cover. Figure 86 shows the appearance of an RCA 733 student instructional terminal.

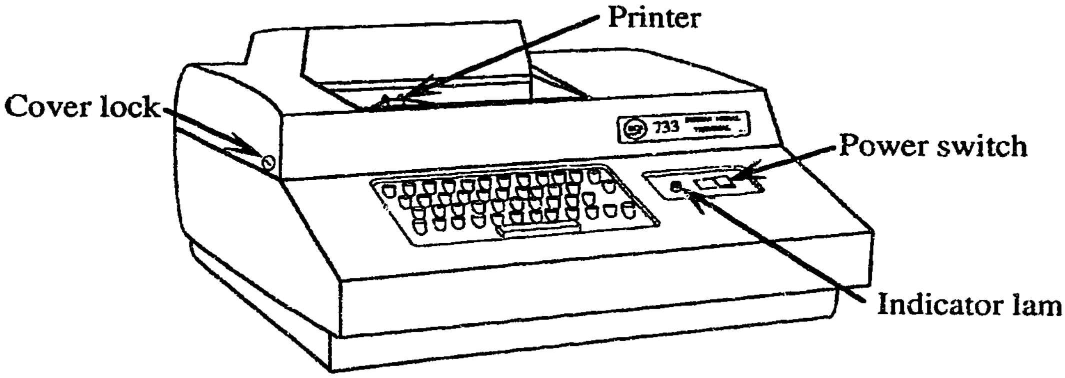


Figure 86. Appearance of an RCA 733 student instructional terminal

The terminal can function in any one of three modes. *Normal* mode, where the terminal may be used by the student to work on a lesson or test. In this mode, an author may also program, inspect records of students' achievement and progress through lessons. *Local* mode permits the terminal to be used as an electric typewriter. RCA considered this feature to be sound pedagogically, since they contend that students not familiar with the keyboard of the terminal might benefit from free practice (RCA Instructional Systems, 1968b). Connection with the computer was not severed completely, however, since a message could be sent to the terminal by the computer. Messages could also be sent by the CPU to the terminal if the function switch was set to the *off* position. In this mode, the terminal could not be used except as a means of displaying messages. Two keys on the keyboard, *rub out* and *ctrl* (control) are intended to be used solely by authors. It is not stated if these keys are disabled when the terminals are used by students.

Like the IBM 1500 system, the RCA system controlled access to lessons and programs through sign-on numbers and it also kept records of student progress and achievement. Instead of using a proctor, the Instructional 70 system was designed so that an ordinary classroom teacher could supervise computer lessons. In consequence, the teacher was qualified only to unstick keys on the terminals, set function switches, request student and class progress and status reports from the computer, and monitor activity at one student terminal at a time (RCA Instructional Systems, 1968b). The teacher was not provided with a special terminal, nor could the teacher attempt to rectify any courseware or system problem unless he/she was qualified as an author or as a system supervisor. It is important to note that while the RCA Instructional 70 system did not use the term *proctor* to describe the teacher supervising students working on the system, the authoring language for the system, ISL-1, contains a statement named *proctor* (RCA Instructional Systems, 1967b). The proctor statement was a priority message system for use by supervising teachers who discovered an operational or courseware problem. When such problems were encountered, the proctor statement was entered followed by information describing the nature of the problem and its suspected location. This information was then printed immediately on the page printer located near the CPU (RCA Instructional Systems, 1967b). If a system operator was present, the problem would be attended to immediately.

As with other large computer-controlled instructional devices such as PLATO and the IBM 1500 system, it is likely that the cost of the RCA Instructional 70 system was considered high by many educators. The lack of a visual display and provision for aural information were likely additional factors contributing to limited sales of the system. A prototype Instructional 70 system was developed within some schools in New York City, and a production installation was made fully operational by 1969 (Feldhusen & Szabo, 1969). This system controlled 192 student terminals, distributed among 16 schools within New York City. It was anticipated that the system would be used to provide lessons in mathematics for up to 6,000 students in grades 2 through 6. Adult students were scheduled to use the system during evenings (Umans, 1969). Although the total number of units manufactured is not known, it is likely to be considerably less than the number of IBM 1500 systems produced, since RCA discontinued the manufacture of the Instructional 70 system by 1972 (Holland & Hawkins, 1972).

Philco-Ford project GROW

In 1966, the Philco-Ford Corporation began designing a computer-controlled instructional system (Charp & Wye, 1968). It should be recalled that Ford, like IBM, had produced computer-controlled instructional devices previously (see section on Tacden machine). Philco-Ford's new system was created in collaboration with the school district of Philadelphia, Pennsylvania. The design project was named GROW, an acronym of the first letters of the four Philadelphia schools involved, Germantown, Roosevelt, Overbrook and Wanamaker (Charp & Wye, 1968). It is not known if inspiration for Philco-Ford's venture came from IBM's announcement of the 1500 system. While most of the hardware of the two systems is different, there are striking similarities between the student terminals used.

The system consists of a main central processor, a Philco-Ford model 211 computer with a magnetic core memory capacity of 32 k Bytes, and 16 magnetic tape drives comprising storage (Charp & Wye, 1968). The main CPU controls four additional processors, all Philco-Ford model 102 computers. Each of these processors is located at one of the participating schools. All are connected to the main CPU through special telephone data lines (Philco-Ford Displays, 1968). These processors are used to control arrays of student terminals at the schools. Lessons are downloaded from the main CPU to the peripheral processors and then to the student terminals. Data from the lessons is gathered by the peripheral processors and is uploaded to the main CPU (Philco-Ford Displays, 1968). The entry into the main CPU, of lessons, student enrollment and scheduling, is achieved by using punch cards (Philco-Ford Displays, 1968). Printers are located at all sites. The printers are used to present summaries of student performance and achievement (Philco-Ford Displays, 1968).

The student terminals are referred to as SAVI, an acronym for *Student Audio-Visual Interface* (Charp & Wye, 1968). Each terminal consists of a CRT display housed with an integral keyboard. The display can generate both characters and line graphics. A light pen is also supplied as an input peripheral with each terminal (Charp & Wye, 1968). It is not known how many terminals were installed at each remote site, or the maximum number of terminals that could be controlled by each model 102 processor.

Charp and Wye (1968) state that courseware design began in November 1966 by a team consisting of curriculum writers, coders, keypunch operators and programmers. It is not stated what programming language was used with the system, but it appears that the Philco-Ford system did not use an authoring language, since coders and programmers were required. Courses were prepared in the subjects of biology and reading, and the system began operation in November 1967 (Charp & Wye, 1968). Although project GROW became operational, little is mentioned about it subsequently. It seems that the system was not marketed widely and that the installation in Philadelphia was withdrawn from service eventually.

TICCET

At least one computer-controlled instructional system was designed to be less expensive to produce than earlier systems. The Mitre Corporation of McLean, Virginia commenced design of this new system in 1967. The system was referred to as *TICCET*, an acronym for *TIme-shared Interactive Computer-Controlled Educational Television* (Stetten, 1971). Besides cost, consideration of which educational groups the system should be intended for was another factor determining design. Stetten (1971) notes that since particular educational groups such as universities and elementary schools usually possess different needs and requirements for the delivery and assessment of instruction, TICCET was developed, "to serve the nation's masses of elementary schools" (p. 36).

It was contended that the cost of the system could be minimized by using common components designed for other purposes, limiting the use of expensive features such as remote links to a mainframe computer and by designing smaller, more efficient processors and storage devices (Stetten, 1971). An array of smaller mini computers were used instead of a mainframe computer. The primary mini computer, designed by Mitre, was to be located at a place designated as the *authoring site* (Stetten, 1971). Entering of courseware and compilation of student records were to be carried out on this mini computer. Although smaller in physical size than many mainframe computers, this mini computer possessed a memory capacity of 64 k Bytes, the same as the larger 1130 model mainframe computers used in the IBM 1500 system. Magnetic tape drives and disk drives were used to store courseware and records.

Instead of using a network of cables or telephone lines to connect the computer to terminals located at remote schools, each remote site was to be equipped with a smaller mini computer with a memory capacity of 8 k Bytes. It was estimated that from between

100 and 300 terminals could be operated by this type of mini computer (Stetten, 1971). These mini computers were also equipped with tape drives, disk drives as well as a special terminal controller called the *Television Display System* or TDS (Stetten 1971). Stetten (1971) attributes the advent of integrated circuits for the existence of the TDS, since a similar unit composed of discrete components would be unfeasible because of size and cost. It is important to note that integrated circuits were not common when earlier computer-controlled instructional systems were designed. The TDS contained character generation circuitry and a hard disk to function as a video buffer in a manner similar to the buffer found in the station control on the IBM 1500 system. The hard disk was also used as a buffer for audio information consisting of spoken words stored in digitized form on disks in the disk drives. A vocabulary of specific words was stored instead of numerous discrete messages as was done with PLATO and the IBM 1500 system. Messages were prepared by the computer selecting and concatenating several words. Stetten (1971) reports that the recorded vocabulary consists of 5,000 words, occupying 10% of the available storage. It is further reported that the size of the vocabulary was considered adequate for most needs.

The cost of student terminals was minimized by using ordinary television sets instead of more expensive CRT monitors designed for computers. It is not noted whether the televisions were monochrome or colour. It was possible to use ordinary television sets with TICCET because the TDS provided information to each television screen at a refresh rate of 30 lines a second, the standard refresh rate of television sets in most of North America (Stetten, 1971). Modifications had to be made to the television sets before they could be used in the system. The speaker had to be disabled and replaced with a headphone jack, so that the television set could be used for individualized instruction. A detached keyboard was selected for each terminal (Stetten, 1971).

TICCET was designed so that no electronic links existed between a remote installation or *school site* and the computer at the authoring site (Stetten, 1971). Courseware and student records were to be transferred between the authoring site and school sites by the physical transfer of tapes and disks (Stetten, 1971). The reasons for this arrangement were to keep costs down and to improve system operation by not slowing the operation of the remote mini computers by requiring them to communicate with the main computer. Unlike other computer-controlled instructional systems such as PLATO and the IBM 1500, TICCET school sites were not intended to be used for creation or modification of courseware. It was considered unlikely that most elementary school teachers possess the time, ability or inclination for such activities in addition to performing their regular teaching and supervision duties. Stetten (1971) states,

> curriculum data [courseware] are generated on the authoring-site computer and then hand-carried to all the school-site computers. The school-site computers use this new, latest edition of the curriculum and generate performance data on the system and on the curriculum materials. These performance data are then hand-carried back to the authoring agency.... (pp. 39-40)

Using the larger mini computer at the authoring site, the disks and tapes are analyzed. On the basis of comments and performance records, changes and modifications are made to the courseware which is then redistributed to the school sites (Stetten, 1971). Himwich (1977) notes that teachers desiring to create courseware may do so by composing the course or lesson on special paper forms. Completed forms are submitted to the authoring site where personnel enter the information and test the operation of the course or lesson. Besides minimizing the skills and responsibilities required of a teacher supervising a lesson at a school site, Stetten (1971) claims, "the decentralized approach also allows a simpler management implementation of the system onto the campus" (p. 41).

It is contended that administrative costs associated with the system are thus minimized. Stetten (1971) states that the estimated cost of a 120 terminal TICCET installation was approximately $25,000 per year, plus $20,000 for maintenance. While $45,000 per year may seem to be a large sum, it was less than for a comparable PLATO installation (see section on PLATO).

TICCIT

While the TICCET system was being developed, consideration was given to the selection of an appropriate theory of learning, development of courseware and a suitable delivery method. Bunderson (1973) states, "Aware of its own educational and social-science limitations, MITRE looked elsewhere for partners to specify educational goals and strategies" (p. 2). In 1971, the Mitre Corporation, with 10 million dollars provided by the National Science Foundation in the United States (Bunderson, 1973) selected a team of developers from the University of Texas at Austin, under the direction of C. Victor Bunderson. In 1972, the majority of this team moved to Brigham Young University in Provo, Utah (Bunderson, 1973). One of the first changes made to the TICCET system was to alter its name and acronym. The original name contained the phrase *Educational Television*. Although TICCET did not resemble this teaching aid, it was likely considered detrimental if individuals equated the computer system with the much simpler and widely-criticized educational television (see Chapter V). The new name selected for the system was *TIme-shared Interactive Computer-Controlled Information Television*, with the acronym *TICCIT* (Bunderson, 1973). Merrill, Schneider and Fletcher (1980) state that the new name was intended to convey the combination of television technology with, "an advanced teaching-learning system" (p. 3).

While most of the basic hardware components of TICCET were retained in TICCIT, the decentralized approach was abandoned. Instead of having an authoring site isolated electronically from the school sites, it was decided that each site would be a self-contained instructional and authoring unit, much like the arrangement of the IBM 1500 system. Each TICCIT installation possessed two mini computers, both Data General Nova 800 models (Hunka & Romaniuk, 1974). One unit, called the *main processor*, controls storage and retrieval and also controls the operation of the second mini computer, referred to as the *station processor*. The station processor controls a modified television display system, a multiplexer, audio unit and optional peripheral devices such as videotape players. Each TICCIT installation can accommodate up to 128 student terminals (Merrill, Schneider & Fletcher, 1980).

Each terminal consists of a modified 12 inch (304.8 mm) diagonal measure colour television and an electronic keyboard equipped with additional keys for special functions (Merrill, Schneider & Fletcher, 1980). Although the system is capable of generating colour images, a full spectral range of colours and tints was not possible because of available storage space and memory requirements. Seven colours, red, green, yellow, black, white, blue and cyan were available. Storage requirements were reduced further by eliminating colour addressing for every screen pixel, totaling 87,720. Instead, the screen was addressed as 1,440 rectangles, each comprising a width of 10 pixels and a height of 6 pixels (Merrill, Schneider & Fletcher, 1980). A rectangle could represent one half of one character. Each terminal is permitted 100 ms access time to the station processor per second. Merrill, Schneider and Fletcher (1980) note that this time interval is dictated by the speed of the mini computers and that processing for an individual terminal may not be completed in one interval. The authors contend that delays are minimal and are unlikely to detract from the efficacy of the system.

While TICCET was intended for use in elementary schools, Merrill, Schneider and Fletcher (1980) state that TICCIT was designed for colleges and some university courses, "the instructional logic which was built into the system assumes adult or almost adult learners" (p. 11). While no mention is made of why the intended market of the system was changed, it is claimed that little data exists about the efficacy of computer-controlled instructional methods with young children, so the instructional logic used might need to be altered to be effective with young users (Merrill, Schneider & Fletcher, 1980). It is also likely that the special keys used with the TICCIT system might be difficult to use by young children, since many of the special keys are labeled with words and the words represent complex abstract concepts in many instances.

Reigeluth (1979) claims that TICCIT represents, "the first extensively theory-based CAI system" (p. 40). While it is difficult to establish an absolute, it is important to recall that some earlier computer-controlled instructional systems, such as those designed by Pask, and those of the System Development Company, were devised on the basis of theories of learning and instruction. Moreover, Jevons' nineteenth-century digital machine for teaching Boolean logic arose from a need discerned from considering theories of learning and methods of instruction (see Chapter IV). Aspects of the theoretical bases of TICCIT are, however, different from those of other computer-controlled instructional devices discussed to this point.

Reigeluth (1979) states that instead of basing TICCIT on a theory of learning, it was based on a theory of instruction. A theory of instruction is concerned primarily with strategies of presenting information and instruction, and with the learner's interaction with them. While it might appear that instructional theories are more practical than theories of learning, it is important to note that instructional theories are based ultimately on some theory of learning, even though the theory may not be stated explicitly. Reigeluth (1979) claims that a new instructional theory, referred to initially as the *elaboration theory of instruction*, was devised in conjunction with the development of TICCIT. Merrill (1988) states that this theory was later expanded and renamed the *Component Display Theory*. Reigeluth (1979) claims that the elaboration theory of instruction was devised because most existing computer-controlled instructional systems seemed to present information according to a rigid, fragmented hierarchical method, usually memorization or drill, and the methods selected were based on the behavioristic system of task analysis. Reigeluth (1979) states further that behavioristic methods of instruction such as drill, "hinders motivation and meaningful understanding" (p. 41). The elaboration theory considers four major design factors, referred to as the *four S's*. The four S's comprise: selecting; sequencing; summarizing, which includes previewing and reviewing; and synthesizing, showing the connections between topics in a given subject (Reigeluth, 1979). Instead of adopting an atomistic approach to instruction, as is the case of systems based on behavioristic tenets, the elaboration theory of instruction states that information should be presented initially from a broad or general overview which, according to Reigeluth (1979) "epitomizes the instructional content rather than summarizing it" (p. 41). This type of overview, referred to as an *epitome*, uses analogies wherever possible. From this general beginning, the latitude of choices is gradually diminished and more detailed instruction is provided. Reigeluth (1979) states, "the general-to-detailed organization allows the learner to learn what s/he wants to learn without having to go through a series of learning prerequisites that are on too low a level of detail to interest him/her much" (p. 43). It is contended further that as the learner becomes acquainted with the subject matter, interest in details will increase, so the objective of the lesson will be attained ultimately. The elaboration theory of instruction is largely cognitive in respect to theories of learning, given that it does not follow behavioristic principles and since it shows associations between *concepts* as well as associations between concepts, procedures and consequences (Reigeluth, 1979; Merrill, Schneider & Fletcher, 1980). Reigeluth (1979) states that there are four major subject/matter associations identified in the elaboration theory of instruction: *conceptual structures*, associations between discrete concepts, identified as discrete by means of a taxonomy; *theoretical structures*, a set of principles referred to as a *model*, that show potential associations between concepts depending upon circumstances and environment; *procedural relationships*, that show specific sequences for the execution of discrete procedures; and *learning structures*, that show any prerequisite learning required for comprehending subsequent concepts and/or principles.

A portion of the elaboration theory of instruction, referred to as *micro strategy* is applied specifically to TICCIT. Micro strategies are the methods of instruction appropriate to a particular topic, while macro strategies are methods of instruction appropriate for a number of related topics (Reigeluth, 1979). In consequence of using a micro strategy, TICCIT is not intended to provide instruction for all subjects. Merrill, Schneider and Fletcher (1980) state that the TICCIT instructional strategy, "is designed primarily for teaching concept-classification and rule-using objectives" (p. 4). The authors define concept-classification as, "the ability of the student to identify previously unencountered objects, events, or symbols as to class membership" (p. 5). Rule-using objectives are defined as comprising two main categories, *procedure-using* and *principle-understanding*.

Although Reigeluth (1979) claims that the instructional theory of TICCIT is new, Bunderson (1973) states that Pask's theories provided inspiration for some of the theoretical aspects of TICCIT (p. 20). Other elements of the TICCIT instructional theory resemble other theories, some of which were postulated as early as 1960. Glaser (1962) describes an analysis of knowledge which finds that verbal or written subject matter used in most programmed instruction and in some computer-controlled instructional systems can be classified into two general groups, *rules* and *examples*. From this premise, Glaser and an associate devised a theory of instruction called the *Ruleg system* (Glaser, 1962). The Ruleg system, which is structured and somewhat hierarchical in nature, assumes that a successful program is dependent upon the statement of the rules to be taught, followed by an ordering or sequencing of them and providing examples or analogies to assist the user in forming concepts of the rules and their relationships to one another. Glaser (1962) states that the elements of the Ruleg system can be related to behavioristic, "programming principles as fading, discrimination training, prompting" (p. 70). While there are similarities between the Ruleg system and elements of the elaboration theory of instruction used with TICCIT, the theories of learning underlying the two systems are different. Merrill (1988) notes that the later Component Display Theory is based on Gagné's theory of learning outcomes, which assumes that different outcomes will follow for different conditions and expectations of learning (Gagné, 1984).

The operation of TICCIT is also similar to other computer-controlled systems. It should be recalled that PLATO used a number of special keys to assist the learner in moving through a lesson or program. A similar arrangement was adopted for TICCIT. Each TICCIT keyboard contains a standard layout of keys. This central portion is flanked on both sides by groups of special purpose keys. The group to the left, called *edit keys*, consist of 13 keys labeled with arrows and English words. These keys are designed to assist the user both in moving the cursor around the screen and in entering typed information such as subscripts (Merrill, Schneider & Fletcher, 1980). The group of 15 keys located to the right of the central keys are called *learner control keys* (Merrill, Schneider & Fletcher, 1980). These keys are arranged in five rows, three columns wide. The keys in the third and fifth rows are black, and the remainder are white. All keys are labeled with English words or abbreviations. The white keys represent functions concerned with specifics of a lesson, while the black keys represent functions related to general instructional matters. The names of the keys are: ATT'N, standing for *attention*, a command that interrupts progress of the lesson or a remedial sequence; EXIT, which terminates the particular lesson in progress; REPEAT, which causes the previous instructional sequence to be presented again; GO, which permits the computer to execute a selection; SKIP, which enables the student to omit the next frame of information or a discrete segment of a lesson; BACK, which permits the user to be returned to the main program after pressing one or more black keys; OBJ'TIVE, standing for *objective*, a black key which causes the terminal to display the objective of the lesson or segment being worked on; MAP, another black key, which presents a schematic or map of the segments of the lesson or course selected; ADVICE, a black key that causes the computer to provide information concerning the user's progress in the lesson or program to this point; HELP, provides further elaboration of a rule or example; HARD, may be pressed when more difficult questions and exercises are desired, also used in conjunction with the practice key; EASY, may be pressed when less difficult questions and exercises are desired, also used in conjunction with the practice key; RULE, a black key which causes the computer to display the rule underlying the segment that the user is working on; EXAMPLE, a black key, presents an example of the rule incorporated in the segment; PRACTICE; a black key, causes the computer to present supplemental practice questions based on the rule being studied currently (Merrill, Schneider & Fletcher, 1980; Bunderson, 1973).

Although Bunderson (1973) contends that TICCIT embodies elements of Pask's theories, its operation is different from many of Pask's machines. While it may be contended that TICCIT embodies principles of fuzzy logic, since the user is not restricted to a single path or level of difficulty through a lesson, decisions as to level of difficulty and subsequent course material are not made internally by the machine, but are made externally by the user through use of the edit keys. In this way, TICCIT operates in a simpler manner than some of Pask's machines of the 1950s. While this difference in operation may seem to indicate that TICCIT is not as advanced technologically as some of Pask's machines, it is important to consider that the theoretical basis of TICCIT is cognitive rather than behavioristic. Merrill (1988) states that the quantity of information learned and retained by an individual, "is a function of the relevant cognitive processing done by the student when learning the information. Passive frames do little to promote such mental activity" (p. 72). Given that the theory of learning underlying TICCIT is cognitive, it is reasonable to expect the user to decide the sequence of course segments and also to decide what level of difficulty is most appropriate.

While it is debatable which theory of learning, behaviorism or cognitivism, and which method of pedagogical control, external or internal, is superior, the configuration of TICCIT illustrates how a computer-controlled instructional system can be made to function according to diverse theories of learning. It is also important to note that while computer technology has become more complex since Pask's machines of the 1950s, computer-controlled instructional systems do not necessarily have to be more complex to function as expected.

While it was intended that the user of TICCIT could solve difficulties encountered in a lesson by selecting remedial and elaborative material from the system, it was realized that some situations require the assistance of a human being. Merrill, Schneider and Fletcher (1980) describe individuals who supervise TICCIT installations as *proctors*. While the duties of a proctor on the TICCIT system are similar to those of proctors on IBM 1500 systems, it is not known whether the idea of proctors for TICCIT was copied from the antecedent 1500 system.

TICCIT was designed so that the creation of courseware was not dependent upon knowledge of any programming or authoring language (Himwich, 1977). Courseware authoring was intended to be a two stage process, authoring and *packaging* (Merrill, Schneider & Fletcher, 1980). The authoring stage entails the entry of the desired subject matter on special paper forms, which force the author to format the material so that it will function as intended when programmed and implemented (Himwich, 1977). The forms also assist the entry of the information into the TICCIT system. The packaging stage of courseware preparation involves the transcription of the information from the forms into TICCIT. Himwich (1977) notes that the packaging or programming may be undertaken either by the author or an entry clerk. An authoring language known as *TAL* or TICCIT Author Language was devised to assist data entry. TAL creates a series of images on the display that resemble the forms. Data entry is accomplished by transferring the information from the forms to the corresponding locations on the electronic images of the forms (Himwich, 1977). Selection of an instructional strategy is unnecessary and not permitted, since it is an integral part of the system.

Although a prototype system was completed in 1973 by Mitre Corporation, large-scale production of TICCIT did not occur until several years later. Merrill, Schneider and Fletcher (1980) report that only six systems were operating by 1979. Only the installations at North Virginia Community College and Phoenix College possessed the maximum 128 student terminals. Of the remaining installations, Brigham Young University possessed 32 terminals, Washington Model Secondary School for the Deaf used 75 terminals, and the San Diego Naval Air Station contained 38 terminals (Merrill, Schneider & Fletcher, 1980). It is not known how many terminals were used at the sixth installation. This system was installed at the Hazeltine Corporation of McLean, Virginia for system testing and development purposes. Hazeltine purchased the commercial rights to TICCIT from Mitre Corporation (Merrill, Schneider & Fletcher, 1980). It seems that a major reason for the sale of TICCIT to Hazeltine was the failure of an anticipated widespread acknowledgment of and demand for TICCIT by educational institutions. Bunderson (1977) states,

> It is clear now that one of our original goals, to produce 'a market success for CAI' was naive. Even if the financial pinch on colleges, and the enrollment decline had not occurred, the technological complexity and the political difficulties were too great to surmount in one five-year project. (p. 7)

Other factors also contributed to the sale of TICCIT.

Financial problems, which appear to have beset most instructional devices discussed to this point, seem to have had detrimental effects on TICCIT. Bunderson (1977) notes that a collaborative effort with General Electric for the design of reading and writing exercises failed ultimately because of disagreements over who was to pay for courseware development and the maintenance of the system. It is also noted by Bunderson (1977) that the "financial squeeze coming from their [universities] governing boards" resulted in the abandonment of several computer-controlled instructional systems, such as the IBM 1500 installations at Penn State University and the State University of New York at Stony Brook (p. 6). Bunderson (1977) contends that TICCIT would survive at Brigham Young University in spite of imposed budget constraints, "because of support from the LDS Church [Church of Jesus Christ of Latter Day Saints, also known as the Mormons] for its potential in developing interactive courseware for newer systems, not for its role in teaching math, English, or any other BYU classes" (p. 6).

Difficulties created by financial constraints lead frequently to political problems. By being forced to obtain funds from independent organizations such as churches and large corporations, a risk is taken of offending or alienating individuals and groups who do not approve of the organizations providing funding. This type of controversy may limit both the credibility and the deployment of instructional devices developed with such funding. Administrators below the board level in colleges and universities can also control the extent to which a particular instructional device is used and developed. Bunderson (1977) states, "departments not only control staffing patterns, resources, and rewards for those who may choose to try TICCIT, but can determine whether anyone will be permitted to try it at all" (p. 6). A combination of financial and political factors may affect the willingness of a staff member to undertake work with instructional devices. College and university administrators may discourage further work by not recognizing and rewarding work already accomplished. Bunderson (1977) states, "Teachers are caught in an incentive system which does not reward involvement with CAI" (p. 6). This view is similar to that expressed by Hunka (The computer, 1972) noted in a previous section.

After TICCIT was sold to the Hazeltine Corporation, Bunderson did not continue work on the system. Besides political and financial considerations, Bunderson (1977) suggests that the era of using large computers for instructional purposes was over because of the advent of the microcomputer. With the aid of a partner, Bunderson started a non-profit corporation called *WICAT*, or *World Institute for Computer Assisted Teaching* which began designing instructional materials for use on microcomputers (Bunderson, 1977). WICAT will be discussed in a subsequent section.

The Hazeltine Corporation made some changes to TICCIT. Merrill, Schneider and Fletcher (1980) note that system memory was enhanced, the storage capacity increased, and a portable terminal was designed. The Data General mini computers were replaced by units designed by Hazeltine. In spite of the improvements made to TICCIT and a concerted effort to market the system, Chambers and Sprecher (1983) report that sales were limited primarily to, "a number of [United States] military training sites" (p. 12). The use of TICCIT in community colleges and universities appears to have declined by the early 1980s, since Chambers and Sprecher (1983) indicate that systems were being used in only two community colleges. During the 1980s, Hazeltine introduced a version of TICCIT for use on DOS-based microcomputers. It is not known if either the mini computer or microcomputer versions of TICCIT continue to be marketed. While TICCIT attempted to be an inexpensive instructional system on which one could create courseware with a minimum of specialized knowledge, it appears that the advent of the less expensive and more versatile microcomputers hastened the demise of centralized computer-controlled instructional devices (Wagner, 1976).

Although other instructional devices employing either mainframe or mini computers were created in the United States and Canada, most were small installations with limited deployment. Moreover, it appears that most of these smaller systems were similar in principle, design and operation to the systems already described in this chapter. It is for these reasons that these smaller systems are not described or discussed further.

Microcomputer-based instructional devices

It is noted in a previous section that Bunderson left the TICCIT project in part because he considered that in future, computer-controlled instructional devices would be based upon microcomputers. The term *microcomputer* refers to a wide variety of brand names, models and configurations of small computers that usually possesses a processing speed, display capability, memory and storage capacities far in excess of most mainframe and mini computers used for instructional purposes previously. As noted in the section about dedicated computer-controlled instructional devices, the advent of very large scale integrated circuits and the capabilities of mass-producing them inexpensively facilitated both the development of microcomputers and their low cost relative to the cost of earlier machines. The use of microcomputers spread quickly in the commercial and manufacturing markets. This rapid deployment, accompanied by much advertising and media promotion, prompted many individuals, especially parents and politicians, to demand that schools present curricula that would prepare students to use microcomputers productively in the work place. Tucker (1985) declares that the impetus for massive deployment of microcomputers in education did not come from educators, but instead,

> came mainly from upper-middle-class parents in suburban communities and in particular from that narrow segment of people who are particularly ambitious for themselves and their children... These microcomputer pioneers insisted that their schools get computers and make them available to students. (p. 14)

This phenomenon was not restricted to areas of the United States. By 1982, the Province of Alberta launched an extensive computer use and deployment project, instigated primarily through action of the Minister of Education, an elected official who did not possess a professional background either in the theory or pedagogy of education (Alberta Education, 1983). The Alberta Education Curriculum Support Branch (1987) states, "Parents impressed by the success of this technology [computers] in the workplace pressured for inclusion of the computer in the school" (pp. 3-4). This quote corroborates Tucker's (1985) observation that politics comprise the primary motivation for public officials encouraging the use of such apparatus, rather than a consideration of articulated pedagogical needs or problems. The actions of Alberta's Minister of Education at that time are similar to those of California's Superintendent of Public Instruction of the early 1960s, who stated that schools should purchase and use teaching machines because parents were buying them (Fine, 1962; see also Chapter VI).

While it seems that some stakeholders in public education appear certain of how curricula should be changed and what equipment should be found in schools, Tucker (1985) states that most of these individuals possess, "no clear notion about what the schools should be doing with computers. Nor did the schools, which had computers... have any idea what to do with the machines" (p. 14). This observation is shared by Hlebowitsh (1988) who states, "Without truly knowing what they were getting themselves into, school administrators authorized the purchase of computers because of political and public relations pressures to do so" (p. 54). The Alberta Education Curriculum Support Branch (1987) considered it the responsibility of educators to ascertain what to do with computers once they were placed in the schools, "It then became the educator's lot to determine where the computer would best fit into the school curriculum" (p. 4). The impression given is that the responsibility of the Department of Education ended with the procurement and placement of computers in Alberta's schools.

Instead of deploying microcomputers to address specific instructional problems or deficiencies, many machines were deployed initially in schools as a solution looking for a problem. Tucker (1985) states, "It hardly helped that this confusion was attended by grand promises, sounded daily in the press, of the coming computer revolution in our schools" (p. 14). This quote is similar to the observation made by Hunka (1977) noted in a previous section on the IBM 1500 system, that some individuals maintain that for a computer to instruct, all one has to do to is connect it to a power source. To be sure, this was not the first occasion when apparatus was promoted by segments of society as being simple to use, immediately practical and essential for future education. It should be recalled from Chapter V, that Thomas Edison promoted the motion picture in the early years of the twentieth century as an instructional device that would revolutionize education by making books obsolete. It is ironic that some zealous promoters of computers for schools make similar claims. Bork (1981) states, "It appears likely that computers will soon be more important in our educational process than books, and, indeed, may entirely replace the book medium for many purposes" (p. 2). While Bork's statement is more guarded than Edison's claim, both are examples of *grand promises* referred to by Tucker (1985).

The phenomenon of mass promotion of an instructional device by manufacturers, the lay public, politicians and some educators, has been described in Chapter VI as the *band-wagon effect.* The notion that educators and the lay public move from one band-wagon or craze to another is noted by several authors. Jonassen (1987) quoted in Chapter VI, states that the pervasive interest in teaching machines was replaced by similar interest in using computers as instructional devices. Ohles (1985) states that innovative instructional devices such as the motion picture, educational radio, educational television, and teaching machines, failed to gain long-lasting use because they were all victims of over-promotion and exaggerated claims as to their importance, efficacy and ease of use. Ohles (1985) also contends that it is likely a similar result will occur with microcomputers, "Possibly no one may stop the computer promoters (assisted by industry using the cream of the advertising crop)... what a tragedy if another highly useful (even if not miraculous) educational tool is misunderstood, over-bought, under-used, and eventually discarded" (p. 53). Similar fears are expressed by Zinn (1978), Hlebowitsh (1988), Ragsdale (1988), and Selsnick (1988).

Instruction in programming

It might seem that the versatility of the microcomputer combined with the bandwagon effect encouraged the development of computer-controlled instructional devices much more than previous types of instructional devices. This is not the case, however. Instead of microcomputers focusing more attention on the presentation of instruction, their versatility and diversity of configuration resulted in many educators abandoning computers as primary and adjunct means of presenting instruction. D'Attore (1981) identifies three main reasons why many educators moved away from using computers as instructional devices. First, it is noted that most courseware is of necessity prepared by teachers and the returns for the time invested are minimal. Second, much courseware contains faults or *bugs*. D'Attore (1981) contends that such problems with courseware result either in student frustration or the inability of the courseware to function in a satisfactory manner. Third, it is contended that machines of any variety do nothing to engender or improve personal relationships, an element D'Attore (1981) considers essential for the occurrence of *meaningful* learning. Instead of using microcomputers as the primary means of presenting instruction, D'Attore (1981) contends that microcomputers should be used as adjuncts to instruction provided by a human being. In spite of such views, factors noted in previous paragraphs have resulted in microcomputers being deployed in schools in different manners.

With the widespread deployment of microcomputers in business and industry came concern by some individuals that education would be passed by this *technological revolution*. This position is not new. Suppes (1966) made predictions before the advent of the microcomputer, that in future, it is likely that computers will be ubiquitous in society. Later, Suppes and Jerman (1969) note that scientific and engineering applications of computers, "far exceed direct applications in education" (p. 41). It may be construed from these statements, that it is insufficient for educators to be concerned solely with using computers as instructional devices. Some individuals share this view and they maintain that students should be provided with the knowledge necessary both to operate computers and to design programs for them. Instead of being used to present instruction in other subject matter, the microcomputer itself became the centre of instruction. Much early instruction in computer programming had no direct practical application in other subject areas in most school curricula. Teaching programming is not a straight-forward process either. In addition to selecting a particular type, brand or model of microcomputer, educators must also select a particular language to use.

A vast array of programming and authoring languages existed by the time microcomputers were introduced in the late 1970s. The large number of different microcomputers prompted a further proliferation of new programming and authoring languages. There appears to be little similarity and portability between languages in general. A language designed for an IBM computer, for instance, will probably not function on an Apple computer without modification. Hunka and Romaniuk (1973) state that there is a tendency among creators of computer languages, "to claim their language as most ideal" (p. 58) an observation also shared by Kleiman (1982). Hunka and Romaniuk (1973) also state that no ideal language which can function on every computer has yet been created. To compound the situation further, some individuals contend that particular programming languages can be used, in and of themselves, as a means of discovery learning, thus returning the microcomputer to the rôle of instructional device (Papert, 1980a; Kleiman, 1982). The diversity and dissimilarity among computer languages may be noted by perusing Appendix C, which lists some programming and authoring languages known to have been used for instructional purposes. The listing is divided into three main categories: *programming languages*, comprising those languages using particular designations and protocols primarily for the creation of programs or functions; *front-end authoring*, languages that interact with the author by means of English phrases, but which generate the course material in some other language, usually requiring further editing to be done in that language; *authoring*, languages that interact with the author by means of ordinary English phrases and which permit editing by means of the authoring language. While the listings in Appendix C are not exhaustive, it is evident by the 110 authoring languages and 51 programming languages listed, that there is little standardization or portability of computer languages. It may be asked what has been done to standardize computer languages for educational purposes and what the results of these efforts have been.

In Canada, the National Research Council attempted to devise an authoring language, *NATional Author Language* or *NATAL*, to operate on many different computers types (see Appendix C). It was anticipated that extensive use of NATAL would create a country-wide standard authoring language. While some individuals and institutions used NATAL, many did not, and most manufacturers of computers ignored NATAL. The goal of a universal authoring language was not achieved, therefore. Through use and subsequent availability, a small number of programming languages gained common use. Among these, BASIC and Pascal are two of the most popular (D'Attore, 1981; Alessi & Trollip, 1985). As with most other computer languages, there are individuals who maintain that neither of these languages are satisfactory for instructional purposes. Although BASIC and Pascal both use English words with special meanings to define particular functions, to use these languages, one must possess knowledge of the English words in the context of computer operations; knowledge of two discrete skills. It follows, therefore, that young students are likely to find using these languages difficult, since several skills must be mastered simultaneously. These factors, among others, encouraged Seymour Papert and associates to design a new programming language based on a consideration of learning theory.

LOGO

As early as 1967, while large computer-controlled systems were the most common instructional use of computers in education at that time, Seymour Papert, a mathematician trained in the theories and methods of Piagét by Piagét himself, began to design a computer programming language for use by young children (Papert, 1980a). The intent of this language is to enable young children, who possess neither advanced mathematical skills or a sophisticated mastery of English, to create operational programs on computer. Papert (1980a) states, "This did not mean that it should be a 'toy' language. On the contrary, I wanted it to have the power of professional programming languages, but I also wanted it to have easy entry routes for nonmathematical beginners" (p. 210). With the assistance of several individuals and funding from the National Science Foundation of the United States, the new language, called LOGO, was developed throughout the 1970s at the Massachusetts Institute of Technology. According to Papert (1980a) the name was selected, "to suggest the fact that it is primarily symbolic and only secondarily quantitative" (p. 210). It is erroneous to consider LOGO as a static computer language, since its original configuration was altered substantially from its introduction in 1968, in response largely to changes in available technology. Papert (1980a) states that at the time the first version was created, "the LOGO system had no graphics. The students wrote programs that could translate English to 'Pig Latin,' programs that could play games of strategy, and programs to generate concrete poetry" (p. 218). Although the initial version of LOGO resembled some other programming languages in general configuration, an actual or iconic representation of the actions comprising commands became an essential feature of LOGO, since Papert intended the language to be used by very young children who would likely be unable to comprehend the abstract meanings of programming commands.

To show the consequences of programming, a device called a *Turtle* was invented. Papert (1980a) states, "The Turtle is a computer-controlled cybernetic animal" (p. 11). Two main types of turtle were invented, neither of which much resembles a living creature. The first type consists of an isosceles triangle generated on the display of the computer. This variety is referred to as *screen Turtles* (Papert, 1980a). Through a command in LOGO (pen down) the movement of the turtle along the display of a CRT will result in the generation of a line that remains visible until a new program is run. While the screen turtle shows the actions of commands and the consequences of programming, Papert (1980a) considered that a more concrete representation might be necessary for some individuals, especially those with learning disabilities. In consequence, a mechanical contrivance that operates apart from the computer was designed.

Called a *floor Turtle*, the apparatus consists of a number of small electric motors, wheels, microswitches and an electronic interface with the controlling computer. Figure 87 shows the general configuration and appearance of a typical floor turtle designed for use with LOGO. For clarity, some components on the circuit board have been omitted.

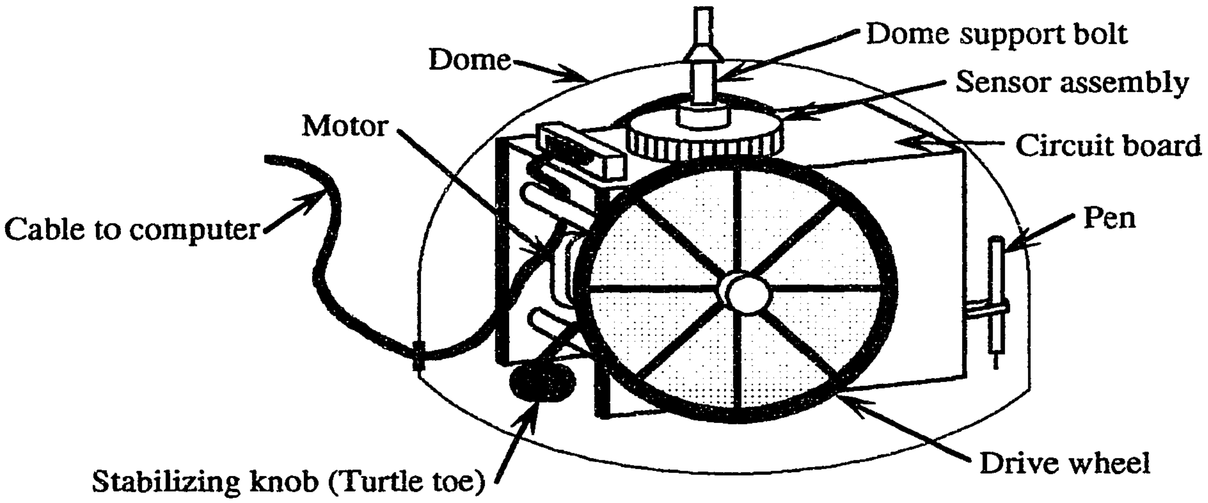


Figure 87. General appearance of a typical floor turtle used with LOGO

The design of the floor turtle is intended to make the unit *childproof* and inexpensive to manufacture (Helmers, 1978). A frame supports a circuit board, a sensing unit and two low-voltage electric motors capable of rotating in two directions. The axle of each motor is connected to a drive wheel to provide navigable locomotion. The turtle is supplied with a ballpoint pen supported by an arm connected to a solenoid which moves the arm up and down. The turtle is connected to the computer through a cable to a parallel port.

From the port, +8 Volts is drawn by the turtle for power (North, 1979). When a command is made in LOGO to move, signals are sent from the computer to the turtle's circuit board. This action results in one or both electric motors being energized. The torque of the motors combined with the shape of the turtle require smooth stabilizing knobs at each end of the frame to prevent the covering dome from being moved downwards and catching on the travelling surface. North (1979) reports that the stabilizing knobs are also known as *turtle toes*. If desired, the LOGO command *pen down* can be executed. This command causes the solenoid to lower the pen. The turtle then draws a line as it travels. The turtle's surrounding clear plastic dome serves a twofold purpose. Besides protecting the components from damage and interference, the dome enables the turtle to sense solid objects in its path. If the turtle is sent in a line that causes it to hit a wall, for example, then pressure is exerted on the dome. This action causes the dome to pull on the supporting bolt. Deflection of the supporting bolt closes a microswitch inside the sensor assembly. The completed circuit causes a signal to be sent to the computer. Papert (1980a) notes that depending upon the design of the LOGO program used, the sensing apparatus of the turtle can enable it to either reverse direction when it encounters an object, or it can be programmed to circumnavigate an object by causing it to alter its path progressively each time a sensor is activated. The turtle is also equipped with a loudspeaker and sound circuitry capable of generating a high and a low tone on command from the computer (North, 1979).

A prototype of the floor turtle was completed in 1977 and commercial production began in 1978 by Terrapin, Incorporated, a company started by some of the individuals involved with the LOGO project (Helmers, 1978). The turtles were sold as kits, each costing $300.00 American (North, 1979). Problems are noted both with adjustment and operation of the Terrapin floor turtles. North (1979) reports that is difficult to adjust the pen. A pen adjusted improperly either lifts the drive wheels off the surface, preventing the turtle from moving, or the pen does not descend sufficiently to mark the travelling surface at all. While the idea of the turtle creating a drawn record of its actions is sound pedagogically, since an iconic representation of abstract commands is produced, North (1979) notes that to be effective and to prevent the turtle from damaging surfaces, paper must be placed on the travelling surface and the turtle restricted to the paper.

Bullough and Beatty (1987) report that other commercial versions of the floor turtle were manufactured. One example, smaller than the Terrapin Turtle, is called the *Turtle Tot*. In spite of its diminutive size, the Turtle Tot also possesses a speech synthesis integrated circuit, available for several languages (Bullough & Beatty, 1987). Through programming, the Turtle Tot can emit verbal statements and commands. Another type, named the *Valiant Turtle*, possesses a housing made to resemble a real turtle. Bullough and Beatty (1987) report that by using the Valiant Turtle, "there is never any doubt about the way it is facing" (p. 218). The authors add that this feature reduces the likelihood of a student becoming confused about LOGO commands and their relationship to turtle movement. The realism of the Valiant Turtle is enhanced further by the elimination of a controlling cable. Wireless operation of the Valiant Turtle is achieved through the use of infrared transmitting and receiving apparatus as well as through a set of 10 nickel-cadmium rechargeable batteries installed in the turtle (Bullough & Beatty, 1987). The novelty and apparent utility of the floor turtle induced Xerox Corporation to include a version in their SMALLTALK computer system (Papert, 1980a).

While the floor turtle is able to transform abstract commands into concrete actions, it was discovered that the versatility of this device is limited, especially when concepts such as velocity and acceleration are to be illustrated. In consequence, many higher-level concepts such as fundamentals of physics rely upon the use of screen turtles (Papert, 1980a). Obtaining sufficient space to operate floor turtles may also pose a problem in some schools. In some instances, Papert (1980b) states that the heuristic principle of letting the student act out a LOGO program is sufficient usually to enable the student to solve problems such as compiling the correct commands to generate a circle. Another factor limiting the use of floor turtles is their cost, since the screen turtle is already part of the LOGO program and functions without the need of additional apparatus.

While Papert (1980a) acknowledges that both the popularity and the utility of the microcomputer increased rapidly throughout the late 1970s, he did not agree with the ways in which most schools were using microcomputers. This criticism extended to the use of programming languages such as BASIC. While he acknowledges that some students develop proficient programming skills through learning BASIC, Papert (1980a) states that in such instances that both the student and computer are functioning in a narrow and inflexible manner. Papert (1980b) claims that the versatility of the computer enables it to be used as ubiquitously as a pencil. Such flexibility, he maintains, is facilitated through the use of programs such as LOGO that are easy to learn, permit the individual to create a program without the need of extensive background knowledge, and which can be used as a method and vehicle of instruction.

Teaching the principles and concepts of mathematics is cited by Papert (1980a) as a prime example of how LOGO can be used to make the subject interesting to most students. Papert (1980a) notes that repetitive practice is a common way mathematics is taught in many schools. While it might seem that the method is satisfactory because pupils appear to learn what is taught and some seem to like it, Papert (1980a) maintains that appearance may be deceiving, "For many school math is enjoyable in its repetitiveness, precisely because it is so mindless and dissociated that it provides a shelter from having to think about what is going on" (p. 51). Furthermore, Papert (1980a) states that the traditional methods of teaching mathematics are examples of what he calls the *QWERTY*. This phenomenon is named for the first six keys on the upper-most lettered row of keys on a standard North American English keyboard. While the layout of the keys was made initially to accommodate mechanical limitations of early manual typewriters, Papert (1980a) sees the continued use of the layout, which he contends is not particularly efficient, to be a form of inertia. Papert contends that traditional methods of teaching mathematics are analogous to the keyboard. Moreover, Papert (1980b) maintains that learning by young children occurs because an observed activity is considered to be important and necessary by the individual, "Children learn to speak because it is a *meaningful* activity... It is not surprising that children do not learn to write when writing serves no real purpose in their lives" (p. 240). Papert (1980b) claims that computers in general and LOGO specifically, enable the individual to observe the principles and concepts of mathematics that were hitherto presented as a set of facts dissociated from any meaning significant to the student.

While Papert, in a manner similar to Skinner, contends that particular methods of pedagogy appear to be obsolete since their rationales are no longer apparent, it is important to consider that methods and conventions that are widely accepted currently may be changed to some degree, but they are rarely replaced outright by new methods and conventions, hence the persistence of the QWERTY keyboard. The development of the English language is analogous. While learning English might be facilitated by using consistent rules concerning spelling and grammar, no one has been able to devise such a system that is acceptable widely. The English language has not remained static through the centuries, however, but is perpetually undergoing gradual change.

Papert's theory of learning and instruction

The theoretical basis of LOGO contains elements of some traditional theories of learning and pedagogy. Some authors such as Watt (1979) and Alessi and Trollip (1985) state that LOGO is based on the theories of the Swiss psychologist Jéan Piagét (1896-1980). While Papert (1980a) states this as well, closer examination reveals that he actually postulates his own theory of learning, based on some elements of Piagét's theories and upon elements of other theories of learning. For example, Papert (1980a) states that his theory incorporates elements of Bruner's theory of learning, especially the hierarchical principle of presenting information in forms beginning with the concrete and progressing to the abstract. Other aspects of Bruner's theory are noted as being incongruent (Papert, 1980a). The strategy of presenting information from concrete to abstract is an element especially important in Papert's theory of learning, since he claims that improvements to computer technology have enabled machines to function in ways analogous to cognitive processing in the minds of human beings. While Papert (1980a) notes that a popular and narrow definition of artificial intelligence or *AI* is the performance by a machine of functions that would be considered indicative of intelligence if performed by a human being, he states that in a broader sense, "The aim of AI is to give concrete form to ideas about thinking that previously might have seemed abstract, even metaphysical" (pp. 157-158).

Although Papert's theory of learning contains elements of Bruner's theory, Papert (1980a) maintains that the fundamental basis of his theory is derived from the work of Piagét. Papert is not concerned with the widely-known developmental aspects of Piagét's theories. Instead, Papert (1980a) states that he is concerned primarily, "with Piaget the epistemologist, as his ideas have contributed toward the knowledge-based theory of learning" (p. 156). The epistemological aspects of Piagetian theory, Papert (1980a) states, have been neglected generally, "because up until now they offered no possibilities for action in the world of traditional education" (p. 156). Moreover, he contends that an educational approach that relies on computers both as instructional devices and as an environment for guided discovery by the student, is capable of incorporating the epistemological aspects of Piagetian theory.

According to Papert (1980a) one epistemological aspect of Piagét's theory is that no separation is made between the process of learning and the content to be learned. In this vein, Papert (1980a) states that the separation of these two elements is the fundamental flaw in learning theories postulated by behaviorists, motivationists and gestalt theorists, "To understand how a child learns number, we have to study... the structure of number, a mathematically serious undertaking" (p. 158). It is also contended that using analogies or reducing complex abstract concepts into simpler abstract concepts are methods that do not achieve the same aim and do not always succeed in enabling the learner to comprehend the main concept being presented. Alternatively, Papert (1980a) maintains that by using Piagét's concept of *assimilation*, the absorption or incorporation of new information into relevant information already resident in the mind, the resulting method of instruction will resemble closely the *natural* way in which young children learn. The turtle, either in concrete or iconic form, functions both as a transition from existing to new information as well as a motivator, especially in the case of the floor turtle (Papert, 1980a).

In essence, Papert's theory of learning applied to pedagogy, a theory of instruction, entails the provision of a computer with suitable courseware to enable the learner to interact with it, so that by manipulating the computer through commands (existing knowledge) new information may be discovered and assimilated into existing knowledge through observing actions presented in a concrete or iconic manner. By using LOGO, the computer does not function as a passive machine. Instead, it interacts with the learner dynamically in a manner that may be considered to be AI in a broad sense.

While it might appear that Papert's theory of learning as applied to LOGO results in a method of instruction by computer that is superior to earlier efforts, other problems affect LOGO. Some problems restrict its deployment as well as its ability to embody Papert's theory of learning. One limitation is imposed by Papert's QWERTY phenomenon described previously. Although some individuals have designed alternate input devices for computers and others such as Owen (1978) have devised more efficient keyboard configurations, the predominant means of individual input to a microcomputer continues to be the standard or QWERTY-type keyboard. It follows, therefore, that the user should possess sufficient keyboard skill to enter information without having to concentrate on the keyboard in addition to the primary task. This assumption, in respect to Papert's theory of learning, means that typing or *keyboarding* skills must be learned prior to learning and using LOGO, so that the entry of LOGO commands may be *assimilated* into the existing knowledge of keyboarding. It would not be appropriate for a student to learn keyboarding simultaneously or for the student to develop his/her own typing method, since Papert (1980a) claims that learning LOGO should not require the student to *unlearn* anything.

Papert's emphasis of the discovery approach in learning LOGO is seen by some to be both inefficient and counter-productive. Bullough and Beatty (1987) state that with LOGO, "Quite a bit of time can be spent in 'discovering' anew concepts that are commonly known" (p. 216). The authors contend further that a discovery method that is somewhat structured, with intervention by the teacher when required, is likely to improve the efficiency of learning LOGO and its implicit mathematical principles. While Papert (1980a) contends that LOGO uses simple and appropriate words as commands, little thought appears to have been given to accommodate individuals possessing poor reading skills and/or an inadequate vocabulary. While LOGO embodies Piagét's concept of assimilation, the significance or meaning of some commands are not always existing knowledge within some users. A child that has difficulty distinguishing right from left, for example, may become frustrated trying to enter the LOGO commands for drawing a rectangle.

An important element of Piagét's theory of learning is the social environment of the child, including language (Piagét, 1966). While English is predominant in much of North America, there are areas where other languages are common. In such social environments, the commands in LOGO bear little resemblance to the existing knowledge of the children . Murray-Lasso (1987) notes that LOGO has little use in Mexico, "a command such as 'LT,' which is short for 'left,' means nothing to a Spanish-speaking child, since the Spanish equivalent... is 'izquierda'" (p. 6). Simply translating commands from English into another language may not be sufficient, since Murray-Lasso (1987) also notes that in some countries, specific areas use different dialects. A word appropriate in one area may not be comprehended in another.

While LOGO does generate iconic representations, both the screen turtle and the graphics generated are crude images. It may be argued that elaborate depictions with a high degree of fidelity are not necessary, since simpler depictions convey the same basic information. While this position may be valid, Papert (1980a) states that one reason why LOGO creates crude graphics is to enable it to be used on the common makes of microcomputers found in schools. Papert (1980a) notes that most microcomputers of the 1970s and 1980s purchased by schools cannot generate graphics with a high degree of resolution.

LOGO is not incorporated into existing curricula easily. Papert (1980a) refers to *LOGO environment* and *LOGO culture*, where an entire class learns subjects primarily through the use of LOGO. While such an environment or culture might be ideal for learning through LOGO in the context of Piagetian theory, the factors of cost and disruption to the teacher and school organization tend to be limiting. There is evidence suggesting that a LOGO culture may not enhance learning. Hlebowitsh (1988) cites several studies which find that the supposed learning of logical thought in LOGO is not transferred by most students to other subjects generally.

In spite of the problems noted, LOGO continues to be used in some schools in North America and Europe. The United States Office of Technological Assessment (1988) reports that LOGO has been modified in some instances to make it more interesting to students. One example is the LeggoLOGO project, where the floor turtle is replaced by mechanical devices constructed of Leggo brand building components. Maintaining interest in LOGO or other computer languages by school-age students appears to be a difficult problem given the rise in popularity of computer-based video games, which many children find more interesting than LOGO. Meltz (1991) reports that Papert has received a grant of three million dollars U.S. from the Nintendo Company to conduct research on how to adapt computer-based video games to instructional purposes. It remains to be seen what the results of this research will be and what impact the findings will have on the development, deployment and diffusion of microcomputers.

Hardware-based microcomputer systems

WICAT

It is noted in a previous section about TICCIT that Bunderson and partners started a non-profit company to develop microcomputer-controlled instructional devices. The company, with headquarters in Orem, Utah, is known by the acronym *WICAT*, standing for *World Institute for Computer Assisted Teaching* (Niemiec & Walberg, 1989). Bunderson (1981) states that much of the courseware developed by WICAT incorporates the rule-example-practice structure comprising the basis of TICCIT. Although Bunderson (1981) notes that some WICAT courseware is designed to be portable between different makes of microcomputers, he acknowledges that there is a large variety of microcomputers available, each with differing attributes such as the amount of memory. It is likely that the plethora of microcomputers, some of which use incompatible operating systems, prompted WICAT to manufacture its own types of microcomputers. By producing their own hardware, WICAT can ensure a uniform hardware configuration at installations using WICAT courseware and hardware exclusively. Variables in courseware operation are minimized in this manner.

Beginning in 1981, WICAT began marketing a microcomputer called *WIT*, standing for *WICAT Interactive Terminal* (WICAT Systems, *Training Systems*; WICAT Systems, *WIT*). The WIT's central processor is a Motorola 68000 integrated circuit, operating at a clock speed of 12.5 MHz (WICAT Systems, *WIT*). The 68000 is the same processor Apple Computer Company selected for the first Macintosh microcomputers, but a slower clock speed is used. Each WIT is also equipped with a detachable keyboard, two RS-232C serial communication ports and a separate 14 inch (355.6 mm) diagonal measure, RGB-type colour monitor. Terminals can be supplied with an optional touch screen (WICAT Systems, *WIT*). Most versions of the WIT do not possess facility for storage, so it is necessary to connect WITs to a central file server through a network. Networks containing up to 32 machines are possible. Different types of terminals are also manufactured to accommodate different training needs. One type permits stand-alone operation by including an integral hard disk and a 5.25 inch (133 mm) diameter floppy disk drive, both installed within the monitor housing (WICAT Systems, *Training Systems*).

In keeping with their *systems approach*, WICAT provides an authoring system with their microcomputer installations. Designed to eliminate the necessity of learning a programming language, *WISE*, or *WICAT Interactive System for Education*, facilitates the creation of courseware including graphics and speech synthesis in certain installations (WICAT Systems, *Training Systems*). Although there are apparent similarities between WICAT installations and older computer-controlled systems such as PLATO, the IBM 1500 system and TICCIT, the operation of WICAT systems are likely faster given that each terminal is a microcomputer with its own processor. In spite of their preference to install their own microcomputer models, WICAT also acknowledges that other microcomputers might already be used by prospective customers. To enable courseware developed with WISE to operate on IBM and similar DOS-based (PC-type) microcomputers, a software program called *WISE Runtime* is available (WICAT Systems, *WISE*).

From promotional literature as well as correspondence from WICAT (letter to S. Hunka from P. Swan, January 7, 1987) it is clear that their microcomputers and delivery systems are designed primarily for industrial training applications. WICAT notes that many such applications require extensive use of illustrative materials as well as demonstration or animation sequences (WICAT Systems, *Training Systems*). While it is possible to store such information on tapes, films and disks as was done in the IBM 1500 system, an array of special apparatus and control circuitry is required. Another disadvantage of using such storage media is speed and accuracy of retrieval. Considering these factors, WICAT designed their systems to use videodisk technology. According to WICAT their, "first commercial focus was on pioneering the use of intelligent videodisc" (WICAT Systems, *Training Systems*).

Measuring 12 inches (305 mm) in diameter and similar in operation to compact disks, videodisks can store a large quantity (thousands) of digitized pictorial and audio information in the form of binary digits, represented as many discrete reflective and non-reflective areas on one surface of the videodisk. A complex digitizer/recorder is necessary to prepare a videodisk master from analogue or digital tapes. Master preparation is usually a time consuming and expensive process. Copies of the master videodisk may be prepared at less expense. The information on the videodisk is retrieved and interpreted by a player which projects a focused low-powered laser beam onto the spinning surface of the videodisk. The beam is moved along the radius of the videodisk. Each time the laser beam strikes a reflective area on the disk surface, the beam is reflected onto a detector, causing it to generate an electronic pulse. Dark areas on the surface do not reflect the laser beam at the detector. Through conversion circuitry, the digital information in the form of intermittent pulses from the detector, is transformed to an analogue signal that is sent to the computer. The videodisk spins rapidly within the player, and the laser beam may be moved quickly along the radius of the videodisk, so little time is required for specific information to be located and retrieved (Woolley, 1979).

Although videodisk technology can both retrieve and present images of high fidelity quickly, the players are expensive. Given the high cost of preparing a videodisk master, it is essential that the illustrative and audio materials selected will not have to be altered in a short time, thus reducing the need for new videodisks. This constraint is usually congruent with industrial training programs that are not usually altered once they are tested and implemented. The same condition is not typical of most school curricula, which are subject to periodic review and revision.

Although WICAT designs its microcomputer-based instructional systems primarily for industrial applications, WICAT systems are used in some schools. Advertisements directed to educators have appeared emphasizing the improvements in academic achievement of students who use WICAT microcomputer systems (WICAT Systems, 1989). Although one installation in a Chicago elementary school is noted, it is not known how many other WICAT installations are used in schools throughout North America. In the late 1980s, WICAT systems were used at the University of Guelph, Ontario and the Ontario Ministry of Correctional Services (letter to S. Hunka from P. Swan, WICAT Canada, January 7, 1987). Available information indicates that few primary and secondary schools use WICAT microcomputer systems at present. Some factors likely responsible for such limited use include cost, little appropriate courseware, and the unsuitability of the hardware and user interface for young children. The direction taken by WICAT in designing and marketing their microcomputer systems for industrial applications rather than for the school market is similar to what was done by many manufacturers of teaching machines. While it seems that industrial and military markets for training are perceived by manufacturers of instructional devices to be more lucrative than schools, there has been at least one attempt at designing and marketing a microcomputer intended for primary and secondary schools.

ICON

Concerned about the diversity of microcomputers available in the late 1970s, and the difficulties educators were experiencing in adapting them to function as instructional devices, a group of Ontario educators, government officials, computer and electronics manufacturers collaborated to design a microcomputer for primary and secondary schools. The intention was to create a microcomputer and operating system that would be easier to interact with by students than any machine or system then available. From this initiative, a commercial enterprise evolved, named the Canadian Educational Microprocessor Corporation or CEMCORP, based in Toronto, Ontario (Herriott, 1985). This company manufactured the hardware and was marketing it to schools by 1983. Through subsidies and other incentives, the Government of Ontario encouraged schools in that province to purchase ICON microcomputers. In one plan, the Government of Ontario contracted the purchase of 10 million dollars worth of ICON computers from CEMCORP. The Government then offered the equipment to schools in that province at a price 25% less than the unit price paid by the Government (Romaniuk, 1983). While companies such as Apple Computer and IBM also instigated programs of placing their brand of microcomputers in schools for little or no cost (Cline, 1986) none of these machines are designed for educational purposes specifically.

As early as the mid 1970s, modified mini computers and rudimentary microcomputers were manufactured by some educational supply companies to facilitate secondary school instruction of computer principles and operation (Electrolab, 1975). While such apparatus could be used as adjuncts to the instruction of computer operation and general programming, the devices are not designed to present prepared instruction in the manner of PLATO or TICCIT. Given that most microcomputers manufactured in the late 1970s were not designed for educational purposes and that their operating systems and languages were complex enough to add to the difficulty of the instruction presented by computer, the need perceived by the designers of the ICON for a microcomputer designed for schools was legitimate.

An ICON microcomputer consists of a plastic housing containing a number of components. Besides a QWERTY-type keyboard possessing additional characters for special functions and for typing French characters, each ICON housing contains a trackball on the right-hand side. The housing also contains a raised portion called a pedestal. The pedestal contains a power switch and is the resting place for the monitor. In some configurations of the ICON, the pedestal also contains a 5.25 inch (133 mm) diameter floppy disk drive. Two types of CRT monitors were available for the ICON. An ICON could be obtained either with a 12 inch (305 mm) diagonal measure amber monochrome, or a 13 inch (330 mm) diagonal measure colour monitor. The resolution of the monochrome monitor is 640 X 240 pixels, while the resolution of the colour monitor is 320 X 240 pixels (Herriott, 1985). Figure 88 shows the appearance of ar ICON microcomputer and monitor, connected to a special file server.

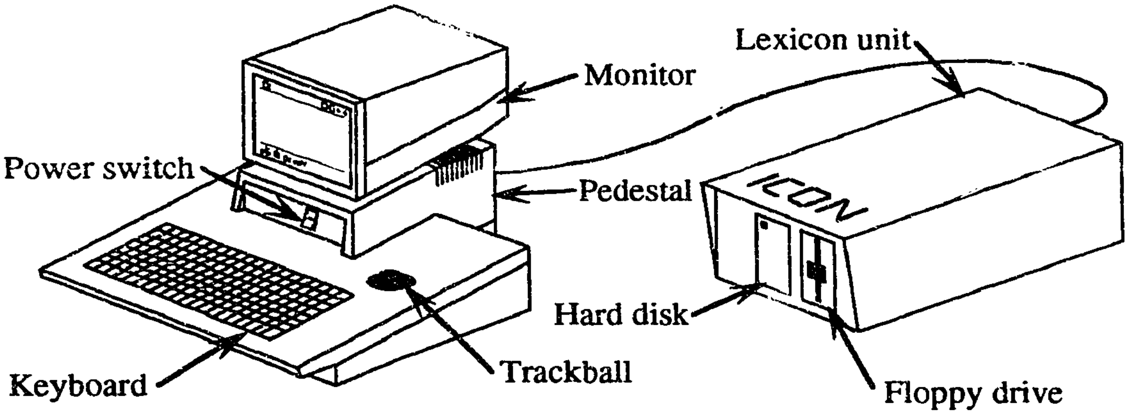


Figure 88. Appearance of an ICON microcomputer and Lexicon file server

The central processor of the ICON is a single Intel model APX 186, 16-bit microprocessor using a 7.8 MHz clock pulse. The standard amount of Random Access Memory (RAM) supplied with each ICON is 384 k Bytes, which can be augmented to 512 k Bytes (Herriott, 1985). The ICON was manufactured in two main configurations. With the addition of a floppy disk drive in the pedestal, an ICON can function as an independent or stand-alone microcomputer. Most ICON installations were designed to use the microcomputer without disk storage. This version is connected to a file server called the *Lexicon unit*, through a coaxial cable network (Herriott, 1985; see Figure 88). The Lexicon contains its own microprocessor as well as a 10 M Byte capacity hard disk and a single 5.25 inch (133 mm) diameter floppy disk drive. Besides controlling the operation of the network, the Lexicon unit permits each ICON to both access and write files on the hard disk (Herriott, 1985). By configuring the ICON to use a file server, a teacher or *site supervisor* can pre-determine what each student will be permitted to access from the file server. In this manner, the individual in charge maintains some control over the system and its use. This feature is similar to many antecedent computer-controlled instructional systems such as PLATO, TICCIT and the IBM 1500.

While the ICON was supplied with several programming languages, including BASIC, Pascal, COBOL, APL, FORTRAN, C, NATAL and LOGO, its operating system differs from that found on any computer available commercially to that time. The operating system for ICON was designed by Quantum Software Systems and is named *QNX*. While the QNX operating system permits the user to execute particular functions by typing and entering commands, such as those for formatting disks and naming files, the operating system can be configured so that the user interacts with a number of small drawings or *icons* displayed on the monitor screen. Each icon is a crude pictorial representation of the function it represents. Some of the icons used in the QNX operating system are shown on the display in Figure 88. When a particular icon is selected by the user, through moving an arrow-shaped cursor on top of the icon by means of the trackball and then pressing the key labeled *Action*, the commands represented by that icon are executed. In some instances, where the icon may represent several possible actions, selecting it will cause a small rectangle to appear on the screen. The actions possible appear as a list of printed words inside the rectangle. A dark bar also appears along the top of the list, causing type beneath it to be printed in a lighter shade. Through the use of arrow keys and the action key, the user is able to move the dark bar down the list and to select the appropriate action. While using icons does not eliminate the complexity of the operating system, it simplifies interaction with the user by relating abstract concepts to more concrete iconic representations. This strategy is congruent with some of Bruner's theories of learning.

In the QNX operating system, several icons and their names are similar to those in the operating system used by the Apple Macintosh computer, introduced in 1984. The rectangles enclosing lists of names of functions also appear in the Macintosh operating system as *pop-up menus*. Although the Apple Macintosh and the QNX operating systems seem to be similar, this similarity is superficial, since programs designed for one system cannot be run on the other. The operating systems themselves cannot be exchanged, since Macintosh and ICON microcomputers each possess different central processors and different ROM routines. Using the QNX operating system on ICON, the user is able to perform some word processing functions and may also create graphic images (Herriott, 1985). Word processing and graphics generation on Macintosh computers require the use of software applications. Other differences between the ICON and the Macintosh soon became apparent to educators once both machines began to be used in schools.

Although supplied with a number of programming languages, little other software or courseware was available for the ICON when it was introduced, a situation similar to the introduction of many teaching machines (see Chapter VI). Within a short time of its introduction, much software became available for the Macintosh computer. Ergonomic design features of the Macintosh make it easier to use than the ICON. The ICON's keyboard and trackball are integral parts of the housing. Problems arise when the machines are to be used by students of widely differing sizes. If the ICON is placed on a table that is the correct height for most students in grade 6, for instance, it is likely that most grade 1 or 2 students will find the table too high. Conversely, placing the ICON on a low table prohibits large students from sitting at the table. While placing the ICON on a high table and providing adjustable chairs is one solution to this problem, it is not as practical or as inexpensive as using a machine that does not create this problem. The placement of the trackball assumes that users are right-handed. A left-handed individual is forced either to use the right hand or to reach across the keyboard with the left hand. These two limitations do not exist in the Macintosh computer. A separate keyboard is supplied with each Macintosh, connected to the computer through a cable. This arrangement enables an adjustable shelf to be placed beneath the table supporting the machine, so that the keyboard may be used easily both by large and small users. Instead of a trackball, the Macintosh is supplied with a mouse. While this pointing device functions in a manner similar to a trackball, the mouse is a separate unit that may be placed on either side of the keyboard, thus facilitating use by left-handed individuals.

Although many Ontario schools purchased ICONs, few were purchased by schools in other provinces of Canada. Little interest in the ICON was shown by schools in the United States. It is likely that poor ergonomic design combined with a paucity of software and courseware and the advent of the more versatile and widespread Macintosh computer were the major factors limiting the deployment of the ICON. While some schools in Ontario continue to use ICON systems, it is likely that microcomputers produced for general purposes, such as the Macintosh and DOS-based personal computers, will eventually displace the ICON entirely.

Current factors affecting use of microcomputers as instructional devices

It appears that the use of microcomputers in schools throughout the western world is ensured for the foreseeable future, since microcomputers are in common use for many purposes throughout these areas. While an adequate description and analysis of computer-controlled instructional devices in the remainder of the world is beyond the scope of this chapter and the limits of this work, a study of available literature indicates that many European, Asian and Australasian countries possess microcomputers (Chambers & Sprecher, 1983; Hooper & Toye; Odor, 1982; Lally, 1982) The available literature also indicates that much of what is done in other continents with computer-controlled instructional devices, follows North American developments closely. While much of the hardware used in Europe, Asia and Australasia is of North American design, much software and courseware is not (see Appendix C for examples). Limited information combined with reports that are widely inconsistent, prevent an accurate description of developments and use of computer-controlled instructional devices in the Soviet Union (Plugin, 1970; Rostunov, 1970; Tikonov, 1970; Landa, 1973; Zender, 1975; Agamirzian, 1991).

As for possible future directions of microcomputer-controlled instructional devices in North America, there are studies conducted both nationally and regionally that indicate the number of microcomputers in schools is increasing (Alberta Education, 1983; Petruk, 1986; United States Office of Technology Assessment, 1988). The findings of these reports suggest, *prima fascie*, that since the numbers of microcomputers in schools is increasing, then the use of microcomputers as instructional devices is also increasing. Closer examination of these reports reveal that they do not list what specific use is made of microcomputers during each class period in each school day. While it is likely that most microcomputers in schools are used by students in various ways, some microcomputers counted in such surveys are used exclusively by administrators and teachers for non-instructional purposes such as the generation of timetables, preparation of teacher lesson plans, recording of attendance, preparation of course materials, test construction, test item banking and the compilation of student grades. Although it may be contended that microcomputers used in this manner assist the instructional process, these machines are not being used as instructional devices, that is, the presentation of instruction to the students directly. The rising numbers of microcomputers in schools may well reflect the increased use of microcomputers for non-instructional purposes. Some studies and accounts such as Petruk (1986) and Ploch (1986) note that some early versions of microcomputers now considered obsolete are being replaced by newer machines. In most instances, the need to upgrade machines is not a need contrived by manufacturers of hardware for additional sales. Ploch (1986) states that newer machines are not only capable of performing more functions than before, but that new software will likely be designed for the newer machines. Moreover, obsolete hardware can also prevent the use of new software. For example, a microcomputer that possesses a tape drive rather than a floppy disk drive is unable to use new software distributed on floppy diskettes. Similarly, courseware prepared with high-level authoring languages like Authorware Professional, also known as Course of Action, require memory capacity, storage capacity and monitor resolutions not present in older microcomputers. While older software and courseware may continue to function on older microcomputers, it may be contended that a school that does not improve both its hardware and software is doing a disservice to students by not providing experience with current technology and content. The problem of upgrading machines adds to the existing problem in most schools of not possessing sufficient microcomputers to instruct entire classes. A possible solution is to encourage students to use microcomputers owned by their families. This could be facilitated through loaning or lending software to such students for use at home. Although there are no statistics to show accurately the number of households with microcomputers, it seems likely that by permitting students to use microcomputers at home, then the number of students who must use school microcomputers would be less. This arrangement could diminish the need for schools to purchase additional hardware. It is important to note, however, that any solution to a lack of computer hardware, software and courseware requires the expenditure of funds.

While it might seem that the perpetual process of avoiding hardware obsolescence through equipment replacement is burden enough on the budgets of educational institutions, some individuals such as Andriessen and Kroon (1980) and Bork (1981) contend that peripheral devices such as videodisks and CD ROMs will become essential components to enable microcomputers to present information and instruction adequately. The addition of such apparatus adds further to the cost of hardware acquisition, upkeep and deployment.

Besides hardware, software and courseware continue to be costly both to prepare and to procure. It was noted in previous sections that between 80 to 100 hours are required for the preparation of one hour of student courseware (Cowper & Romaniuk, 1975). Ploch (1986) notes that the cost of a single instructional program for microcomputers may run as high as nine million dollars. Moreover, Ploch (1986) states that unless governments underwrite the cost of courseware development, then individual schools or jurisdictions must pay high prices for copies of the courseware. Catalogues of software and courseware designed for school use are available to assist with selection of appropriate programs, but the unit cost of most such software ranges from about 20 dollars to over 200 dollars (Mattas, 1986). While it might appear that a single class set of a particular program is not too costly, it must be borne in mind that a single piece of software or courseware is rarely sufficient to meet the curricular needs of a particular school or district. When several programs are deemed necessary, then the total cost for software/courseware becomes prohibitive.

Copyright laws that make no provision for the limited funds of educational institutions also ensure that schools will have to spend much money to obtain sufficient copies of courseware and software. Such legislation combined with poor funding ensures that most schools will be unable to make extensive use of microcomputers. It is fitting to leave the last word on the factor of cost and school funding to Alfred Bork, quoted at the outset of the section introducing microcomputers, as claiming that books might be replaced by computers (Bork, 1981). Dismayed by the lack of financial support both by the private sector and by the United States Government for the use of computers as instructional devices in schools, Bork asks, "Is education really a national goal, or do people merely want to pretend it's important?" (in Ploch, 1986, p. 50)

Although cost is a formidable factor affecting the development and deployment of instructional devices generally, there are other factors that may limit the use of computers in educational institutions. Possible long-term effects on health through prolonged use of particular computer hardware, are just beginning to be noted and considered. Bullough and Beatty (1987) note that radiation and electromagnetic fields emitted by microcomputer CRT monitors, especially colour monitors, "may enhance such problems as eyestrain, backache, irritability, and neck strain" (p. 42). The design of some keyboards may contribute to muscle and tendon strains in the hands, wrists and arms. Although there is little evidence to correlate positively CRT monitors and keyboards with physical ailments, educators should not dismiss these factors or trivialize them. It is possible that the same parents who agitated strenuously for the inclusion of microcomputers in schools may apply equal effort to have them removed if they believe that such equipment presents possible harm to their children. If additional evidence is produced that correlates CRT monitors with physical dysfunction, then it is likely that governments will create legislation forcing the modification of existing hardware, a large expense. In anticipation of such a development, it might be prudent for educators to consider some earlie. hardware designs of computer-controlled instructional systems. It should be recalled that the PLATO IV system used plasma displays. Besides permitting the rear projection of transparencies (microfiche in this instance) plasma displays consume less power than CRT displays and plasma displays emit no radiation and negligible amounts of electromagnetic fields. Bullough and Beatty (1987) claim that new monitor technology is not yet developed to the extent that plasma displays can be used with microcomputers, illustrates how an ignorance of past developments in education can lead to needless delays and senseless reïnvention. Some individuals may claim that the educational market is too small to dictate equipment design. The creation of the ICON microcomputer shows that educators can establish hardware design standards for education, although it seems that in this instance the educators concerned were not communicating with commercial enterprises, since the Macintosh computer appears to have been developed simultaneously.

Although several factors are noted that may limit the deployment of computer-controlled instructional devices in schools generally, there are other factors that facilitate the use of microcomputer-controlled instructional devices in specific circumstances. There is evidence to show where computers in general and microcomputers specifically, meet needs in special education. Odor (1982) notes that microcomputers not only provide a means of communication for many physically and mentally disabled people, but microcomputers are also well suited to providing instruction to such individuals. With the provision of suitable peripheral devices, microcomputers can present information to many disabled users in ways that are more efficient than many methods used by living instructors (Odor, 1982). It should be recalled from the section in this chapter concerning the IBM 1500 system, that Hunka (The computer, 1972) notes that computers cannot ridicule or demean a student in full view of other students. In the same vein, microcomputers used to instruct disabled people are capable of infinite patience and discrete personal instruction, attributes which may not always be present in teachers who are human beings.

Microcomputers are important instructional devices in the area of neurological rehabilitation. While Feer (1985) states that this area of rehabilitation is less than 20 years old, it is one area of rehabilitation that has adopted the use of microcomputers rapidly. Loftus and Loftus (1983) report that using microcomputers to present learning tasks relevant to neurological rehabilitation results in greater motivation than similar tasks presented by machines designed for that purpose specifically. The authors describe a case in which a patient could not move both eyes synchronously as the result of a closed head injury. The patient was prescribed activity on a machine that projected two point of light on a screen. The points of light are moved randomly about the screen by a mechanism inside the machine and the patient is expected to learn to follow the points of light with the eyes. In the manner of a teaching machine, the machine is set to increase the speed at which the points of light move gradually. While the apparatus functions as designed, Loftus and Loftus (1983) report that boredom with the machine leads to eventual reluctance of the patient to use the apparatus, resulting in a consequent delay in eye tracking improvement. A computer-based video game that requires the tracking of objects was substituted. Loftus and Loftus (1983) report that the game increased patient motivation for the therapy and also resulted in a faster improvement of tracking skills than occurred using the light point projector. As noted in several previous sections, the principle of sufficient motivation is an essential element in most theories of learning and pedagogy (Gage & Berliner, 1988).

Another aspect of neurological therapy entails the controlling of stress and frustration brought about by the dysfunction. It is contended by some researchers that excessive stress levels will prevent learning from taking place (Hebb, 1955; Bourne & Ekstrand, 1976; Feer, 1985). Bourne and Ekstrand (1976) report that mechanical feedback devices have been devised to provide individuals with auditory and/or visual representations of particular brain waves. Through such biofeedback, it is contended that self-control of one's level of arousal may be learned by moderating particular brain waves. Although biofeedback machines have been manufactured for some time (Bourne & Ekstrand, 1976) such devices are intended usually for one purpose only. Given that schools and other educational institutions usually possess limited budgets for capital items, it is unlikely that biofeedback devices will be purchased. Bourne and Ekstrand (1976) also note that the effectiveness of using biofeedback to control arousal level is not a therapy that is accepted universally. In consequence, it is likely that many students that could benefit by such therapy may not receive it.

Considering these factors, biofeedback programs and necessary peripheral devices for biofeedback have been designed for microcomputers and have been tested with school-age children. Bowers (1991) reports that microcomputer-based biofeedback may be implemented in schools using existing microcomputers. It is also noted that microcomputer-based biofeedback therapy is a recent advent that may not be deployed quickly because of cost considerations.

Conclusions

In this chapter, the development and deployment of computers as instructional devices has been described and discussed as well as the theories of learning embodied in them. It has been shown that while some computer-controlled instructional devices were developed from the principles and techniques of programmed instruction and teaching machines, many other computer-controlled instructional devices were developed by individuals in other disciplines such as computing science and electrical engineering. Similarly, it has been shown that different theories of learning can be embodied in computer-controlled instructional systems. Such flexibility was not possible with simpler teaching machines. While the flexibility of the computer enables it to present information according to many different theories of learning, this flexibility has also facilitated continuing controversy as to which theory of learning is most effective and appropriate when applied practically. Noting the apparent diminishing interest in using computers as instructional devices, Vargas (1986) B. F. Skinner's daughter, contends that it is the selection of inappropriate and flawed theories of learning that have resulted in the current loss of interest in using microcomputers to present instruction. It might seem that a computer-based instructional system embodying the important elements of a single theory of learning might diminish some confusion about which theoretical approach to use, since it forces the adoption of a single theory. Previous examples show that this approach does not work. It is noted in Chapter VI, that many teaching machines designed during the late 1950s and early 1960s embodied the principles of Skinnerian behaviorism only. The result of such a singular approach was that many individuals criticized teaching machines as being too inflexible and incongruent with other theories of learning in use. This perceived inflexibility of teaching machines contributed to their eventual abandonment by most educators. It is apparent from information presented in the other chapters, that a consensus on a single theory of learning or a particular pedagogical approach is unlikely if not impossible.

The ability of most computers in embodying principles of different theories of learning likely prompted the development of instructional theory, the consideration of practical and theoretical factors in the implementation of instructional devices. The Component Display Theory, arising from work with TICCIT, is one example of an instructional theory. Similarly, Papert's development of LOGO forced him to draw elements of different instructional theories together in conjunction with practical considerations, to design a programming language that would also be an effective vehicle for instruction. While it is important to consider which theories of learning or instructional theories should be embodied in computer-controlled instructional devices, it has been shown in this chapter that other factors may determine both development and use of computer-controlled instructional devices.

From the examples of Jevon's logical machine through CEMCORP's ICON microcomputer, it is apparent that the long-term use of computer-controlled instructional devices is dependent upon perceived need by those individuals and institutions that are the intended users of the machines. As with many teaching machines (see Chapter VI) needs differ between the intended users of computer-controlled instructional devices and individuals and authorities not involved directly with the presentation of instruction. It has been shown in this chapter that disregarding the concerns and needs expressed by the intended users does not result either in a rapid deployment of the instructional device or in an appreciation of the needs expressed by those individuals not involved directly with presenting instruction. A consequence of trying to force the use of instructional devices without addressing the concerns of the intended users, is either cautious and limited use of the instructional device, or an eventual rejection of it because claims of the device's performance and efficacy are at variance with what is experienced in practice by individual educators. Many of the factors that impinged upon earlier instructional devices, such as cost, ease of use, availability of appropriate curricular material, also impinge upon both the development of and use of computer-controlled instructional devices. It seems that cost, both of hardware and courseware is a predominant factor in this regard.

It has been shown that even experimental systems, such as the IBM teaching machine project, were constrained in their selection of hardware because of cost restrictions. It has also been shown that cost factors resulted in several institutions terminating their use of IBM 1500 systems. Recalling the quotes of Bork, the factor of cost has forced him to alter his prophecies of the future rôle of computers as primary means of presenting instruction. Further discussion of the associations between such factors and the development and use of instructional devices is presented in Chapter IX.

New factors such as possible health hazards and rapid hardware obsolescence may alter the predicted development and deployment of microcomputers for educational purposes. To be sure, the proliferation of microcomputers in the business and industrial fields will ensure that computers will remain in schools and other educational institutions in the foreseeable future. It remains to be seen whether computer-controlled instructional devices will be used as teaching aids in the manner of the blackboard and the abacus, or whether computer-controlled instructional devices will be used as primary means of presenting instruction. While it has been shown in several chapters that few individuals have made predictions with great accuracy, it seems appropriate for educators and the developers of instructional devices to consider previous events and developments with instructional devices when considering new instructional devices and the methods by which they may be used most effectively. By doing so, it may be possible both to avoid repeating mistakes of the past and to avoid unnecessary re-invention of devices or the rediscovery of principles. For example, it is noted in a previous section that Bunderson and others considered the microcomputer the only type of computer worth pursuing for educational applications since microcomputers are small, powerful, self-contained and less expensive than most larger computers. While the logic of this position appears clear, subsequent deployment of microcomputers in classrooms suggests that larger computers might be better suited. The advantage of a self-contained unit seems to be nullified by the apparent importance of connecting all microcomputers within a classroom or even an entire school to a network. The operation of most networks is usually slow and inefficient compared to the operation of larger computer systems designed to serve several terminals, such as PLATO, TICCIT and the IBM 1500 system. The point of this example is not to advocate a return to using older computer-controlled systems. The point being that educators should consider their needs as well as the properties of available and previous hardware before committing themselves to particular systems. It is easy to defend what has been done in ignorance of past developments by stating, "at the time, we did not know any better". While this defence may be acceptable for situations and circumstances that could not be foreseen, it is unacceptable when actions are taken without considering the wealth of previous developments and events and applying that knowledge to present endeavors.

While this chapter has described and discussed the development of most computer-controlled instructional devices and the theories of learning and instruction that they embody, one area has been omitted on purpose, simulations. Although many simulations are created and controlled presently by computers, the development and use of simulations has evolved prior to the advent of computers. The complex nature of some simulations combined with their application to many disparate educational situations warrants a separate treatment. Simulators are described and discussed in Chapter VIII.

Chapter VIII

Simulation and simulators

Introduction

Many of the instructional devices described and discussed in previous chapters may also be classified as *simulators*. Some authors such as Naylor, Balintfy, Burdick and Chu (1966), Lewis and Smith (1979), and Taylor and Walford (1978) contend that the term *simulator* also includes art, games and aspects of engineering. Other such as Gibbs (1975) contend that some games may be considered simulators, while others may not be. A definition of *simulator* in the context of instructional devices is difficult, since there is no consensus in the literature. Some researchers, such as Lewis (1975), Chandor, Graham and Williamson (1977), Bratley, Fox and Schrage (1983), Alessi and Trollip (1985), Minsky (1985), Wager and Gagné (1988), and Mandell and Mandell (1989) contend that a simulation is a mimicking of behavior or it is a logical, but simplified representation of reality. While many simulators function in these ways, others do not.

Bases of simulations and simulators

Simulations of ideas or concepts may represent a reality, but the reality is valid and logical primarily within the confines of the idea or concept, and this representation of reality (also referred to as *virtual reality*) may not be congruent with actual reality as perceived by most individuals. This concept is different from that postulated by Lewis and Smith (1979). The authors contend that all simulators are simplified representations of reality that function either in a consistent manner, or seem to function unpredictably, according to an implicit *stochastic* process. The distinction postulated by Lewis and Smith (1979) does not explain simulations of abstract concepts, ideas and theories. One example of such a simulator is the so-called *Turing machine* created by the British mathematician Alan Turing (1912-1954) in 1937 (Augarten, 1984). Turing devised a theoretical machine that functions according to particular rules of mathematical logic, to assist his response to questions of the proof of logic advanced by the German mathematician David Hilbert (1863-1943) in 1928 (Augarten, 1984). Turing describes his machine as a mechanism that can move a tape of infinite length, divided into boxes of equal dimensions, past a scanner and an erase/write head. The machine is capable of only three actions: scanning an individual box and then stopping movement of the tape; erasing a symbol in the scanned box and then writing a new symbol in it; and scanning an individual box and then moving the tape a number of boxes either to the right or to the left (Kemeny, 1955; Augarten, 1984). The simulation of a machine enabled Turing to transform his logical response from abstract concepts into more tangible symbols comprehensible by many individuals. In this way, Turing's simulation attempted to create a virtual representation of abstract ideas. Turing never constructed such a machine, and it would be difficult to do so, since it is not possible to construct a tape of infinite length. Augarten (1984) contends that Turing's simulation embodies many of the logical functions inherent in most modern computers. While Turing created his machine largely from abstract concepts, the functioning of many digital computers, devised subsequently, corroborates that many of Turing's concepts are reflections of reality as perceived by most individuals.

Consideration of simulators that transform abstract ideas into tangible form is especially important in respect to artificial intelligence. While the term *intelligence* is used freely, it does not always refer to quantifiable attributes such as behavior or physical and chemical changes in the brain. Some cognitive theories of learning contend that intelligence also comprises *potential* for learning as well as the ways concepts are arranged and associated within the mind (Best, 1989). Since intelligence cannot be explained fully in a quantifiable manner, simulations or instructional devices that are referred to as intelligent, conform to the concept of *intelligence* accepted by the creator of the simulation. Others may not accept that definition or concept of intelligence. Pollio (1974) notes that in 1950 Turing, responding to the question "can a machine think?" states that the answer is dependent upon the definitions of the words *machine* and *think*. To define these terms in respect to common attributes of human beings and machines is not a simple matter, since there are attributes of some machines, which will be noted and discussed subsequently, that confound such attempts.

It is evident from the foregoing, that simulators arise from one of two bases; an actual object, sequence or event, or from an idea or concept. The ability to create either type of simulation is dependent largely upon suitable available technology (Price, 1964). Figure 89 shows the representation of the two theoretical bases of simulators in schematic form.

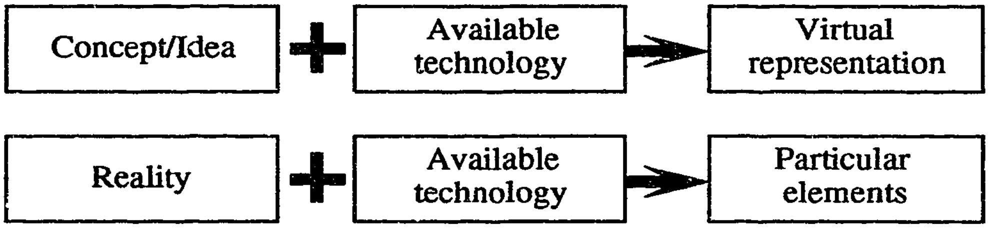


Figure 89. Schematic representation of the two theoretical bases of simulators

Examples of both types of simulators may be found in the ancient world (see Chapter II). Archimedes' planetaria as described by Cicero, simulate part of the cosmos in a tangible way based on the concepts of Stoic philosophy. The technology available to Archimedes was sufficient to enable him to create a transformation from abstract concepts to concrete simulations. While the devices were likely used as teaching machines, they also functioned as simulators according to the aforementioned definitions. Although the devices worked in an apparently realistic manner, the underlying idea they reflected, that of a geocentric solar system, was erroneous. While the devices seemed to simulate reality, they were actually representing reality as explained by Stoic philosophy. Similarly, the devices described by Hero of Alexandria, used to teach principles of Stoic and Epicurean philosophy (see Chapter II), were also simulators of the type that represent concepts in a tangible form. Like Archimedes' planetaria, the representation embodied in Hero's simulators is at variance with reality as defined by empirical and quantifiable scientific evidence. The error, of assuming that a successful simulation of a concept means that the concept is valid, is difficult to discern without quantifiable evidence that the underlying theory is wrong. This assumption may also impede the subsequent gathering and interpretation of quantifiable evidence that refutes the concept embodied in the simulation. The difficulties experienced by Galileo Galilei in refuting the concept of a geocentric solar system is one example of this phenomenon.

Discriminating factors

An example of a simulator derived from an actual object, event or behavior is the quintain. While there is little doubt that it was intended to teach particular psychomotor skills and techniques, the quintain is also a simulation of an adversary. Elements of reality are missing from the quintain both intentionally and through limitations of design and available technology. The degree to which a simulator resembles the actual object, process or behavior is referred to generally as *fidelity*. The element of fidelity may be applied to the simulator as a whole, or it may refer to particular aspects of the simulation. While the goal of practice on the quintain is improvement of swordsmanship, it is counter-productive to have recruits learn these skills by practicing against a living, experienced adversary intent on killing any opponent. It is desirable to provide practice that will lead to improved skills while also retaining some of the less-lethal attributes of an adversary. The quintain does this through its feedback. The feedback provided by the quintain possesses less fidelity than that provided by an actual adversary, yet the fidelity of the feedback is sufficiently high to encourage the recruit to modify his behavior. The palus (see Chapter II) possesses a lower degree of fidelity in this aspect than the quintain. As noted in Chapter II, it is likely that the quintain was developed to increase the fidelity of the palus to facilitate appropriate unsupervised learning and practice by recruits. The depiction of the Roman quintain in Chapter II, shows a crude device that little resembles a human adversary. It may be said that the appearance of this variety of quintain possesses *low-fidelity*. Although the Romans were capable of carving wood and other materials to resemble human beings, human features do not seem to have been considered necessary to the learning process in this instance. In many instances, the degree of fidelity is a function of the explicit goal of the simulation. In the case of the Roman quintain, for example, the instructional goal was to teach a particular psychomotor skill, rather than reinforcing an association between physical attributes and an enemy. A designation of high or low fidelity of a simulator can be dependent upon the instructional goals of the simulation, therefore.

Some computer-controlled simulations of digital or logic circuits permit individuals to design digital circuits and to *test* them through simulation. These programs, such as *Logic Simulator*, devised at the University of Alberta, and the *Schematic Designer* by Douglas Electronics, can also be used as instructional simulations. Figure 90 (created with Schematic Designer) shows two schematic simulations of digital or logic circuitry.

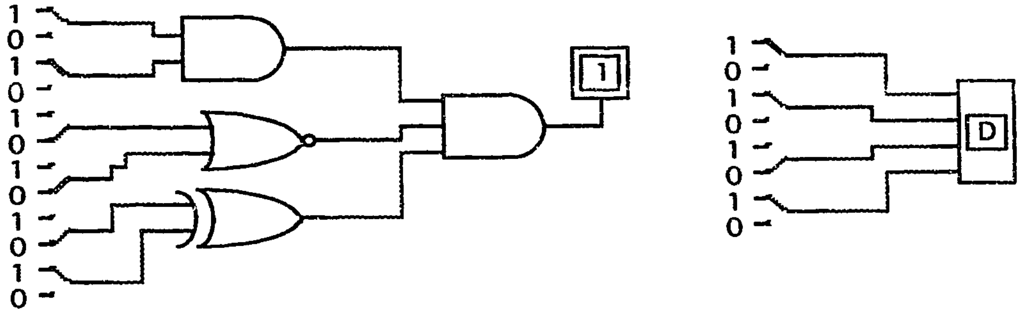


Figure 90. Schematic simulations of two logic circuits

The first circuit shows one of two possible combinations of numbers that change the state of an electronic lock control, while the second circuit illustrates, in a tangible way, the connection between binary states and hexadecimal notation. Besides drawing the schematics of digital circuits, the programs also interact with the user to show the operation of the circuits constructed. It is for this reason, therefore, that the second circuit shown in Figure 90 displays the hexadecimal number *D*. Changing the state of any input will also result in a corresponding change to the hexadecimal number displayed.

While a student may learn how particular logic gates and other components may be connected and how such circuits can function, the fidelity of this type of simulation can be either high or low, depending upon the goal of the simulation. If it is intended for the student to learn only the characteristics of particular logic components, then this type of simulation possesses a high level of fidelity. The simulation is a tangible manifestation of particular abstract concepts, therefore. No connection is made with concrete reality, however. Although the circuits and principles represented in the simulation happen to reflect reality, it is not possible for a student to transform the knowledge gained from the simulation into the concrete action of constructing circuits without additional information. The fidelity of the simulation would be considered low, therefore, if the instructional goal of the simulation is for the student to be able to construct the circuits with actual components. Given the information in the simulation, one could construct the circuits using a wide variety of components ranging from vacuum tubes to integrated circuits. The simulation does not provide instruction as to which type of component should be used, or how any of them can be connected together properly and what power supplies are necessary to drive them. Fidelity, therefore, is not necessarily an attribute of simulation that can be considered in and of itself. Establishing instructional goals that are congruent with the capabilities and attributes of a simulation are essential if the simulation is to be an effective instructional device. Besides the context of instructional goals, there are other considerations that affect the treatment and evaluation of fidelity.

Failure to make a distinction between *attribute fidelity* and *fidelity overall* may lead to pedagogical problems when simulators are used as instructional devices. For example, Pollio (1974) notes that while a phonograph obscured from view in an adjacent room may be perceived by a listener to be an actual human voice, the simulation possesses high-fidelity in only one aspect. It is erroneous to contend, on the basis of only a few attributes, that phonographs possess high-fidelity overall, since they neither resemble human beings, nor can they simulate most behavior of human beings. To attempt using a phonograph as a simulation of a teacher, a practice advocated by some individuals in the past (see Chapter V) is invalid, since the ability to speak is only one attribute of a teacher that is necessary for effective pedagogy and class control.

It is noted in Chapter III, that some mediæval quintains were fabricated to resemble human beings. The higher fidelity of this aspect, compared with earlier Roman quintains, was likely intended to increase motivation or the emotional level of the trainee. While appearance of the quintain does not contribute directly to the improvement of the skill being taught, it may be contended that introducing more elements of reality into the simulation, increasing the fidelity overall, facilitates the transfer of the skills learned from the simulator to the intended situation (Robinson, 1927). A simulation that has too many elements of reality removed, may be so dissimilar to the actual situation it is supposed to represent that the learner will be unable to transfer what has been learned from the simulation to the actual situation. On the other hand, adding too many elements of reality may make learning difficult, since the attention of the student will be divided among more elements, some of which may not be essential to what is intended to be learned (Fox, 1960). It is a matter of debate as to what constitutes an optimum degree of fidelity overall to ensure appropriate transfer of learning (Alessi, 1988). Examples will be presented to show how the question of fidelity is not addressed either easily or consistently.

Closely related to fidelity is the attribute of *dimensionality*, the actual or perceived appearance of two or three dimensions. Some simulators derived from actual objects, procedures or behaviors, are represented in two dimensions rather than three. In spite of this transformation, many of these simulators are considered effective in teaching particular skills and/or knowledge, even though what is learned is to be applied in a three-dimensional environment. One example of this phenomenon is a simulation of a hand-held calculator on a computer screen. Although the simulation is two-dimensional, most individuals are able to interact with it in a way similar to how they interact with an actual three-dimensional calculator. Skills or knowledge learned on one, are likely to be transferred easily to the other, therefore. While it might appear that the element of dimensionality is two-state, given that an object can be either two or three-dimensional, examples of simulators that are partly two-dimensional and three-dimensional will be described. Through optical illusion, for example, some two-dimensional simulations appear to be three-dimensional.

Another major attribute of simulators is whether the simulation is *static* or *dynamic* and *interactive*. By the definitions presented previously, a photograph may be considered a simulation. While the photograph may possess a high degree of fidelity in one aspect, appearance, there is little that the observer can do to interact with it, save the addition or deletion of lines and shapes through graphic manipulation. The interaction is static compared with the quintain, which reacts variably to the input of the user. Some simulations may be *dynamic* without being interactive, however. A wind tunnel containing a model of an aircraft is a dynamic simulation in that wind is forced past the model. The rôle of the observer or user is largely passive rather than interactive, although the simulation is acting dynamically with the model aircraft. The element of dynamicism can be considered as a continuum, as with the other elements described so far, rather than as two or three fixed states.

Related to all three attributes mentioned thus far is *time*. While the principles of heredity may be discovered by having students perform experiments with generations of fruit flies, the process is slow and the required time may not be available. Some simulations of this process can decrease the time required to see the results of selective breeding to a few seconds. Conversely, some events that naturally occur quickly, can be slowed down in some simulations to accentuate significant aspects and/or attributes of the event. In some instances the simulation may represent one particular time only. Models of fœtuses or diseased organs, for example, simulate development or degeneration at a particular time.

Figure 91 shows by way of a two-dimensional graphic simulation of the author's concepts, made to appear three-dimensional, the associations between the attributes of simulation described to this point.

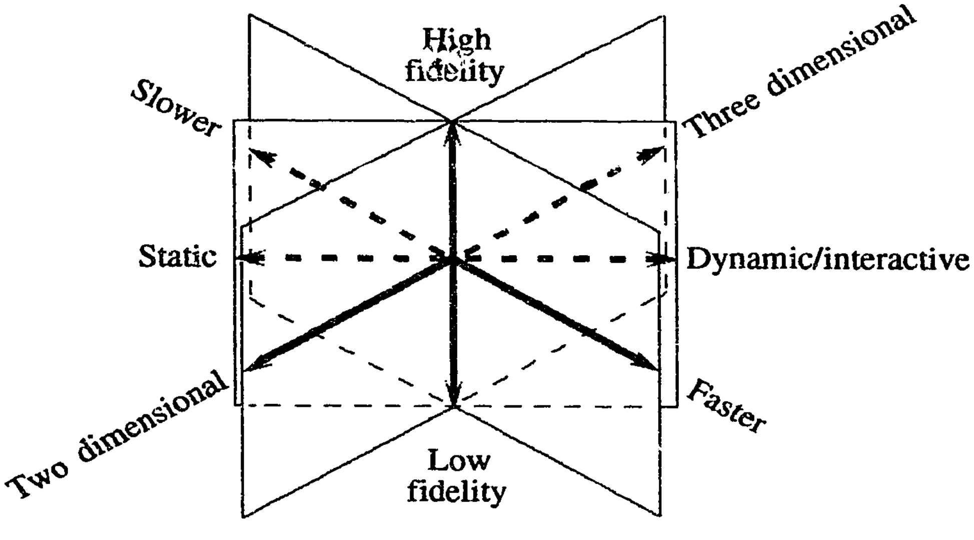


Figure 91. Representation of the associations between simulation attributes

It should be noted that there is no consensus on definition of the terms used. By providing definitions at the outset of this chapter, it is anticipated that consistency will be ensured and that the prospect of confusion will be kept to a minimum. The drawing is not intended to imply boundaries of attributes or that a particular point or area constitutes the proper mixture of elements to create an *ideal* simulator. The model is intended to show how it may be possible for an infinite variety of simulations to be prepared by combining these attributes in different ways and degrees.

It is evident from the previous discussion that many simulators are intended to be instructional devices. It may be contended that particular types of simulators, such as wind tunnels for testing models of aircraft, are not instructional devices since they are devised for testing purposes. These simulators, nevertheless, function as instructional devices in the broad sense of education, since they do impart information to the observer that was not already present. The knowledge gained from such simulators, for example which wing designs are resistant to being sheared off an aircraft, is transferred to actual situations. If no learning takes place, then subsequent wing design will not incorporate any of the information revealed by the simulation.

It is also apparent from the examples described previously, that different simulators conform to different theories of learning. It is noted in Chapter II, that the quintain seems to function in accordance with some theories of learning described contemporarily as behavioristic. Observational learning as explained by Bandura (1965) appears to be the theory of learning embodied in some wind tunnel simulators. While it might seem from the foregoing discussion that the term *simulator* is synonymous with *instructional device* or *teaching machine*, there are examples of simulators designed solely for entertainment purposes (Price, 1964). Examples include some ancient devices intended to entertain observers by imitating specific behavior (Bedini, 1964b; Price, 1964). Other examples include simulations of eyes, hands, arms and other body parts intended as prostheses for disabled individuals. Some simulators, such as the crude, coin-operated representations of animals and spacecraft found in many shopping malls and in some stores, are intended primarily for the amusement of young children. More complex simulators, such as mechanical bulls and some so-called video games usually found in places of entertainment, may also be used for instructional purposes. Rodeo performers may gain practice by using mechanical bulls, and some hand-eye coördination therapy and practice methods use video games. Extremely complex simulators have also been designed solely for the purpose of entertainment.

One example is the SR2 unit manufactured by Doron Precision Systems of Binghamton, New York. Intended to be deployed indoors as an amusement, the SR2 is a rectangular housing that can contain up to 12 individuals. A film projector within the housing displays special sound motion pictures inside. The housing is supported by several hydraulic cylinders that are activated and controlled by computer. The correct sequence of actions by the hydraulic cylinders is determined by special read only memory (ROM) chips, synchronized with the film. Motion, sound and visual cues are combined to simulate a number of events (Doron Precision Systems, 1988a). Eighteen different simulations were available for the SR2 in 1988, ranging from simulations of roller coasters (simulations of real events) to a simulation of a space battle (simulation of abstract concepts or ideas) (Doron Precision Systems, 1988b). It is not always easy or appropriate to relegate simulators to particular categories.

Model railroads have existed in the western world since the nineteenth century and they are considered to be a form of entertainment generally. Some of these miniature simulations of transportation systems are also used for instructional purposes. Munson (1991) describes how he has used the construction and operation of a model railroad in his school to teach a variety of skills, principles and information. In this instance, a simulation intended for entertainment is being used both as a teaching aid and as a teaching machine. Munson (1991) reports that the simulation engenders a high motivation in most students. Intrinsic motivation is apparent since students appear to enjoy interacting with the simulator and most express a desire to continue working with it and learning from it.

This chapter will describe and discuss simulators known to have been used as instructional devices, either as teaching aids or as teaching machines. While some simulators may be considered teaching machines, it is important to note that most simulators are not devised in the manner of most mechanical and electro-mechanical teaching machines. It is noted in Chapter VI, that Pressey, LaZerte, Mowrer, Skinner and others devised their teaching machines from the basis of one or more theories of learning as ways of simulating aspects of a real teacher. Although it can be shown that some other simulators were devised in the same way, the majority appear to have been devised from a consideration of other factors. These factors will be described and discussed subsequently. Unlike the development of teaching machines, the development of simulators and simulations has not been limited to individual countries. It is for this reason that in general, the discussion of simulators will not centre about geographic areas.

While the previous discussion indicates that some of the instructional devices described in other chapters may also be considered simulators, this chapter will concentrate upon devices not already described.

Simulators for medical education

Buck (1991) contends that although some of the earliest simulators date from ancient times, none appear to have been applied practically to the education of medical practitioners. This contention is valid only in respect to dynamic/interactive simulators, and the article exemplifies how it is difficult to establish a definition of a term that is used widely. There is evidence to show that static simulations were used for medical education as early as 2000 B.C. Blaine (1951) describes a three-dimensional model of a sheep's liver made of clay, believed to have been used in the education of Babylonian medical practitioners. The term *model* is used rather than simulator. Some individuals consider static representations to be models and more dynamic/interactive representations, simulators, although it appears difficult to define lines of demarcation between models and simulators. For example, Zeigler (1976) describes classroom-based driving simulators as "simulation models" (p. 6). Applying the definitions described in this chapter previously, static models will be considered simulators. Examples of other early static simulations include bronze sheep livers dating from about 500 B.C. and drawings of human musculature dating from the sixteenth century A.D. (Blaine, 1951; Hilloowala & Renahan, 1985).

While static two and three-dimensional simulations were used in medical education for many years, no need was perceived for dynamic/interactive simulators until the sixteenth century A.D. It seems that pedagogical methods for medical instruction up to this time usually had no provision for dynamic/interactive simulators. The preferred method of instruction for most subjects during this period, was lecturing supplemented with books (Buck, 1917). Although some doctors such as Mondino de'Luzzi (1275-1326) employed cadavers to supplement their lectures, the use of dynamic/interactive simulators either for individual practice or for demonstrating difficult procedures or rare conditions to classes does not appear to have been considered. The availability of suitable natural objects (cadavers and animals) as well as the existence of static anatomical models likely satisfied the limited need for instructional materials during these periods (Blaine, 1951; Hilloowala & Renahan, 1985).

Obstetrics simulators

The situation changed by the mid sixteenth century A.D., when concern was focused upon the apparent causal relationship between the use of midwives and a high infant mortality rate (Jameson, 1936). Although most doctors of that time possessed sufficient knowledge to be of greater assistance in child birth than most midwives, it was considered largely inappropriate for doctors, nearly all of whom were males, to work in an area generally considered to be the realm of women (Buck, 1917). As well, the practice of obstetrics suffered a low social status at that time (Jameson, 1936). The large number of children who died or were maimed by improper handling during parturition, as well as complications to or fatality among the mothers caused by midwives, led to the introduction of licensing laws in European countries as early as the late sixteenth century (Speert, 1973). The need for properly trained midwives induced some doctors to offer special courses for practicing midwives, as well as for women desiring to become midwives. Most of these first attempts consisted of lectures supplemented with illustrations ment in the way midwives performed is a probable reason for the development of obstetrical simulators. One of the first such simulators was developed in France by one or both of the Drs. Grégoire. This father and son team, noted for their positive reputation as teachers of midwifery, taught during the late seventeenth and early eighteenth centuries in Paris primarily (Smellie, 1876; Johnstone, 1952).

The Grégoires' simulator

The Grégoires created a manikin intended to simulate the abdomen of a human female. This contrivance is sometimes referred to as a *phantom.* The simulator could reproduce, in a simplified manner, the birth of a child and some related complications of a sort that would require a trained professional to rectify successfully. Although there are no known illustrations of the Grégoires' device, it is possible to obtain a rudimentary understanding of it from surviving descriptions. The apparatus consisted of a human pelvis contained in a basket-work frame. The pelvis and the immediate area were covered with an oil-skin, while the remaining portions were covered with a coarse cloth. The oil-skin was probably used to simulate the genitalia. Real fœtuses, likely preserved by some means, were used in conjunction with the manikin (Smellie, 1876). By manipulating a fœtus within the manikin it would be possible to simulate a variety of birthing complications. The midwives could receive practical *hands-on* experience with this method. If an error was made, the procedure could be halted immediately and the mistake corrected. In respect to the model presented in Figure 91, the Grégoires' simulator possessed moderate fidelity in the aspect of child birth, although the fidelity of the simulator overall was probably low. The Grégoires' simulator was entirely three-dimensional, and it was used in a dynamic/interactive manner. The speed of the simulation could be varied at the pleasure of the instructor who controlled the simulation.

Using a simulator for instruction in this instance has several distinct advantages over training with real births. First, trainees may make mistakes with the simulator without placing an actual woman or a live fœtus in peril. Second, trainees can be shown complications that they might otherwise not observe while attending an actual birth. Third, the simulation can be stopped at any point and it can be repeated. Fourth, distraction is kept to a minimum, since the trainee needs to concentrate only on the simulation and the instructor, not to largely irrelevant behavior of the *mother.* Fifth, social taboos related to observing womens' genitalia are not violated. It may be asked why this type of three-dimensional, dynamic/interactive simulation was used at that time when none seem to have been used in earlier medical instruction.

Although it is possible for surgeons to obtain practice by operating on animals, a similar arrangement is not readily available for midwives. While it is not difficult to have a large number of student surgeons present at a scheduled operation, it is not as easy to assemble a number of midwives to observe a birth, given that births cannot usually be scheduled to a precise time. A simulation, in this case, is ideal. In this instance, the simulator fulfilled an evident need that could not be satisfied in any other way.

Following the model shown in Figure 89, available technology was sufficient to enable the creation of a simulator embodying several aspects of reality. The use of some actual parts of human beings both assisted the creation of the simulator as well as increasing its fidelity. The creation of the Grégoires' simulator was also possible since it meets Schlebecker's (1977) four essential elements for the invention of a technological innovation: (1) accumulated knowledge; (2) evident need; (3) economic possibility; (4) cultural and social acceptability (p. 650; see also Chapter II). There was evidently sufficient accumulated knowledge to fabricate the simulator. There was evident need, as indicated previously. No components of the simulator were expensive, and so it was economically feasible to construct. Social acceptability does not appear to have been a major problem, although some midwives criticized the presumed efficacy of learning from an inanimate

The low overall fidelity of the Grégoires' simulator concerned some individuals of the period who knew of its existence. Some of these individuals contended that the simulator does not resemble a human being at all, " 'tis so rude a work that a common pelvis stuck into a whale without any embellishment would be as like nature as this machine which has been so much admired" (in Smellie, 1876, p. 14). While it seems that individuals learning midwifery skills from the Grégoires' simulator could transfer the skills to actual births, at least one physician maintained that the low overall fidelity of the simulator impeded satisfactory transfer of learning from the simulator to actual situations (Jameson, 1936).

Smellie's simulator

William Smellie (1697-1763) was an English surgeon and medical practitioner who developed several obstetrical instruments, and who is also noted for being a foremost teacher of midwifery in the eighteenth century (Jameson, 1936). Smellie, who studied obstetrics under the younger Dr. Grégoire, developed more elaborate simulators to assist with instruction in obstetrics (Johnstone, 1952). Instead of using a basket-work frame, the frame for Smellie's simulator used bones from the skeleton of a human being. Smellie (1876) describes the covering material as smooth leather with the interior spaces stuffed with "an agreeable soft substance" (p. 14). A uterus that could be dilated and contracted was also fabricated and included inside the simulator (Johnstone, 1952). It is not certain what material comprised the uterus. Some means of simulating amniotic fluid and blood was probably present as well, since Mrs. Nihell, a midwife who did not approve of Smellie's simulators, describes a bladder, "This bladder was stopped with a cork, to which was fastened a string of packthread, to tap it occasionally and demonstrate in a palpable manner the flowing of red-colored waters" (in Johnstone, 1952, p. 26). As well as increasing the fidelity of the simulator, the inclusion of pseudo amniotic fluid provides a cue as to the progress of the simulation. The presence of amniotic fluid provides tangible evidence that the amniotic sac is broken and that the birth of the child is imminent. The release of the fluid was under the control of the instructor operating the simulator. This action is an example of a *controllable* process.

Unlike the Grégoires' use of real fœtuses, Smellie constructed artificial fœtuses from wood and some unknown elastic substance. One of Smellie's students describes the pseudo fœtuses in this manner, "The Children for these machines [simulators] are likewise excellently contrived, they having all the Motions of the Joints. Their Craniums are so formed as to give way to any Force exerted, and are so Elastik [sic] that the Pressure is no sooner taken off than they return to their natural Equalities" (in Johnstone, 1952, p. 25). Smellie's concern with fidelity did not end there. Artificial afterbirth composed of different varieties of leather was also used, perhaps to simulate the condition of a retained placenta. The fidelity of the simulator in respect to the parts of the body related to child birth seems to have been high. Dr. Camper (in Johnstone, 1952) a contemporary of Smellie, states, "the contraction of both the internal and external os, the generation of water in parturition and dilation of the os uteri are so natural that hardly any difference is to be noticed between these, and those in natural women" (p. 26). Smellie constructed at least three childbirth simulators, and six pseudo fœtuses (Findley, 1939; Johnstone, 1952). It is not certain, because of insufficient descriptions, whether the simulators were identical or whether each was designed to simulate a particular set of problems.

The higher fidelity of Smellie's simulators did not alter the concepts being taught. Instead, the more realistic appearance of the devices seems to have been intended to facilitate the transfer of learning. Although Smellie's devices were well received by most lay people and by some other medical practitioners, there were critics. Besides those criticisms made by Mrs. Nihell, mentioned previously, others considered the simulators

Babies, which have rather amused than instructed your Pupils" (in Johnstone, 1952, p. 26). In spite of such criticism, Smellie's simulators continued to be used after his death. The ultimate fate of the simulators is unknown. It is important to note that Smellie's method of teaching midwifery was not confined to using simulators. In addition to using detailed charts and drawings, he also used preserved fœtuses and female cadavers (Johnstone, 1952). Smellie's use of simulators was not unique at that time, since other contemporary physicians and practitioners both designed and employed simulators for instructing midwives. One of the most notable of these was Sir Richard Manningham (1690-1759). Although extensive descriptions of his device are lacking, it seems to have been similar both in construction and purpose to Smellie's simulators (Spencer, 1978).

Other simulators for obstetrics

Although simulators of this sort continued to be used for some training in obstetrics, they did not gain widespread use during the remainder of the eighteenth and throughout most of the nineteenth centuries. Cost, reluctance to adopt new methods of instruction, skepticism that what was learned from a simulator could not be transferred to actual practice, are some of the factors that contributed to the limited use of obstetric simulators. There is evidence to show that obstetric simulators were used when there was an apparent need for them. For example, an American physician, Dr. Richard A. F. Penrose (1827-1908) used a simulator to teach childbirth techniques (Chianfrani, 1960). Penrose's manikin, called *Mrs. O'Flaherty* was likely similar to those designed by Smellie, although the lack of a detailed description precludes further comparison.

There was a great need for Penrose's simulator, since social considerations of the time discouraged most medical students (the majority being male) from attending an actual birth. Chianfrani (1960) contends that the result of this situation was that most medical students of the late nineteenth century graduated without receiving any direct experience with childbirth. Although the fidelity of Penrose's simulator did not equal that of an actual birth, the use of the simulator would provide medical students with at least some experience with birthing techniques and with some of the related complications.

The need for simulators to assist with the general teaching of obstetrics has been diminished by the development of technologies such as cinematography and television coupled with the gradual elimination of unskilled midwives and the relaxation of some traditional social taboos. Training in some specific obstetrical procedures, especially those that could pose an undue risk to the fœtus or the mother if they are performed incorrectly, may still require the use of simulators. In consequence, many modern simulators are designed to provide practice in specific obstetrical procedures. An example of such a simulator is one intended to assist nurses and midwives in mastering the skill of attaching scalp electrodes to a fœtus *in utero*. The device, formed of plastic primarily and marketed by the United Kingdom firm of Adam, Rouilly Ltd., consists of a simulation of the lower portion of the female torso. Inside, a cervical canal, dilated os and a simulated fœtal head are provided. The device is further equipped with electronic sensors that are connected to a control console (Adam, Rouilly Ltd., 1988). The console indicates whether or not the actions of the user are appropriate. In this manner, the simulator assists the user in developing skill according to accepted procedure. Except for the vagina, the fidelity of the external appearance of the simulator is low. The fidelity of the relevant internal components is high, however, since it is the internal components that are relevant to the particular procedure being simulated.

The earlier obstetrical simulators mentioned previously were intended to provide instruction in basic obstetrical anatomy and in particular procedures. In these instances, an overall high degree of fidelity was considered essential so that the student, who usually possessed either limited or no medical experience, could transfer the knowledge gained from the simulator to a real situation without difficulty. An implicit assumption with the Adam, Rouilly simulator, therefore, is that the user possesses at least some basic knowledge of obstetrical anatomy and procedure. The use of a simulator in this case is considered desirable since it allows practice without disturbing pregnant women and their fœtuses, or without placing them at risk. There are other areas of modern medicine where simulators are also a most appropriate means of instruction.

Resuscitation simulators

Medical personnel as well as the general public are encouraged to become competent to administer mouth-to-mouth ventilation techniques as well as cardiopulmonary resuscitation (CPR). Although it is possible to learn the theory and the principles of these techniques by means of lectures, illustrations and demonstrations, it may be argued that competence in performing these procedures can be gained only through experience. While some practice in mouth-to-mouth ventilation can be obtained by using live participants, CPR cannot because of the risk of harming the participant. Live participants for mouth-to-mouth ventilation practice may not always coöperate properly, so the experience gained may not be useful in an actual emergency. The risk of passing contagious diseases through bodily contact is another disadvantage in using live participants.

These considerations were among the factors which motivated a Norwegian doll and toy maker, A. S. Laerdal, to develop a line of manikins that would simulate human beings sufficiently to enable them to be used for resuscitation training (Gordon, n.d.). Laerdal introduced his manikin which he called Resusci-Anne, in 1960. It is a life-size representation of a young adult female complete with appendages, hair, a realistic face and clothing. The simulator is largely composed of various plastics, including the skin which is life-like in both appearance and touch. The first versions of Resusci-Anne were designed to teach mouth-to-mouth resuscitation solely, so the trachea and the lungs were the only internal organs simulated. The fidelity of the internal organs is low, as the airway consists of length of plastic tubing and a plastic bag simulates the lungs. The operation of the simulator, nevertheless, reflects a high degree of fidelity. Unless the head is tilted back sufficiently, for example, the airway will be obstructed by a small bar located inside the manikin's neck. This condition simulates the obstruction of an actual trachea by the tongue. Instructive feedback is provided to the user by means of colored indicator lamps. The lamps comprise parts of electrical circuits which are completed when certain microswitches within the manikin are closed. If sufficient ventilation is being provided, for example, then the circuit connected to the green indicator lamp is completed. In addition, the lung is arranged so that its inflation and deflation cause the chest of the simulator to rise and fall (Seireg, 1987). Although the Resusci-Anne possesses an high degree of fidelity overall, there are several attributes including heart beat, pupillary changes and skin colour that are not simulated.

In the interest of user safety, there is one attribute designed to have low-fidelity. In the usual practice of mouth-to-mouth resuscitation, air that has been blown into the lungs of the victim is expelled through the mouth and the nose after the resuscitator removes his or her mouth from the victim. The exhalation of air from the victim indicates that the resuscitation technique is effective. Although the passing of respired air between one individual and another entails the risk of passing certain contagious diseases, the risk is not usually a primary concern of the resuscitator. There is little to be gained, however, by exposing students unnecessarily to such a risk. With this concern in mind, the internal parts of current versions of the Resusci-Anne are designed so that exhaled air from the manikin is exhausted from a port in the side of the chest rather than through the mouth and nose. While this action does not simulate exhalation accurately, it reduces the risk of disease transmission between users via the resuscitation simulator (Hudson, 1983). It may be argued that the low-fidelity of this one aspect of the simulator is compensated for by feedback provided by the coloured lamps.

Later versions of the Resusci-Anne also contain a spring and piston mechanism within the chest cavity to permit CPR techniques to be learned and practiced. The spring and piston mechanism simulates the resistance of the breastbone and ribcage to being depressed. An indicator lamp array, a paper recording mechanism or an optional computer connection enable the apparatus to provide instructive feedback to the user on whether or not the technique used is effective and to what degree (Pinchak, Hancock, Hagen & Hall, 1987).

In addition to the Resusci-Anne, Laerdal also makes a simulator in the form of a baby, called Resusci-Baby, as well as a simulated youth called Resusci-Junior (Laerdal Medical, 1989a). Like the Resusci-Anne, the two smaller versions are designed to provide simulations for the purposes of resuscitation and CPR training. The smaller versions are considered important because some adult resuscitation techniques are inappropriate for babies and youths (Seireg, 1987).

It seems that many medical practitioners contend that the use of manikin-based simulators for resuscitation and CPR training is more effective than either lectures or presentations using films or similar media, since the student is forced to demonstrate and to practice his/her skill when interacting with a manikin. Wynne (1986) reports that while most hospitals possess manikins for training purposes, many hospitals do not use them effectively, so many classes do not gain a satisfactory level of proficiency. Besides too little practice time on the simulators, Wynne (1986) reports that several training programs do not provide sufficient background information before practice sessions, so that many students learn acceptable procedures from the manikin in time-consuming *trial and error* fashions. Wynne (1986) also notes that while manikins are used widely for training medical practitioners, their use is rare in schools. It is contended that instructing life-saving skills to young children such as mouth-to-mouth resuscitation and CPR, enable these individuals to be helpful in some emergency situations where immediate intervention is essential for the continued survival of a victim. For the reasons noted previously in this section, Wynne (1986) argues that manikin-type simulators are the most viable means of providing such instruction and skill practice. While it is not feasible to have one manikin-type simulator for each student, Wynne (1986) states that in an ideal situation, "There should be no more than four to six students per manikin" (p. 32). While manikin-type simulators tend to be expensive instructional devices, their obvious practical benefits to the well-being of individuals, may induce educators and funding agencies such as governments, to increase the use of such simulators in schools.

While it may seem that most simulators for medical training are designed to have an overall high degree of fidelity, there are a number of simulators produced that possess a high degree of fidelity only in a few areas, typically those attributes and conditions most associated with the concept being presented. It is intended by the designers and manufacturers of such simulators that they will be used by personnel that are already familiar with general procedures with patients, but who require practice with a specific manœuvre on a particular part of the body.

Intubation and bronchoscopy simulators

In the case of intubation practice, it is important that the laryngoscope is inserted correctly and without excess pressure on the teeth. Correct tube placement is also essential for the well being of the patient. Given that the procedure is unpleasant at best for a patient, there is little opportunity for practice. With these factors in mind, most intubation simulators consist of a manikin head with high-fidelity of the external appearance. Depending upon the complexity of the simulator, some either contain a simulation of the trachea while others, designed for practice in bronchoscopy as well, also contain a simulation of the nasal passages. Most models are also equipped with a battery-powered indicator lamp that lights if the laryngoscope is pressed against the teeth with excessive pressure. The simulated tracheas of some versions of this type of simulator are fabricated of clear plastic, so that the user can observe the effects of his/her actions as well as providing a visual indication that the intubation tube has been placed correctly (Laerdal Medical, 1989b).

Infusion simulator

Infusion is another procedure that is difficult to practice on a patient. To provide such practice, simulated human arms usually fabricated of various plastics have been devised. While the external appearance of these simulators have low-fidelity, the simulated veins and the movement of colored fluid through them have high-fidelity. It is possible, with such a simulator, for an individual to gain practice both in injection techniques and in the introduction of intravenous cannulæ (Laerdal Medical, 1989a). By injecting colored fluids into this simulator, the user receives immediate feedback as to whether or not the injection was successful or whether an intravenous cannula is positioned correctly.

Simulators for cardiology

One area in medicine that seems to use more simulators than any other is cardiology. The use of simulators appears to be prevalent in two main areas, training in defibrillation techniques and in diagnosis. In both areas, actual patients are not suitable either for practice or for providing examples of all possible conditions a cardiologist might encounter. For defibrillation training, like training in CPR, a simulator is required, since it is dangerous to practice defibrillation techniques on a healthy patient, and to practice on a patient with a fibrillation may place that patient in greater peril. Simulators that permit practice in defibrillation do not require a high level of fidelity overall. The area of the chest must possess high-fidelity to ensure the transfer of learning from the simulator to an actual patient when required. Some simulators of this variety consist of an artificial torso, while others consist of an entire manikin. Internal fidelity is usually low, since these simulators usually contain electronic sensors to relay the position of the defibrillation paddles to the control unit or monitor (Spivak & Miller, 1967). The simulator may simply provide feedback on paddle placement, or if the device is complex enough, it may simulate a variety of fibrillations that require slightly different defibrillation techniques. Most of the more complex simulators are controlled by a computer. The use of computer-controlled simulators is greatest in the area of cardiac diagnosis.

To be sure, there are simulators for training and practice in cardiac diagnosis that are simple enough not to be controlled by computer. One example is a device called the *Heart Sound Generator* manufactured by Cardionics Incorporated. The device consists of a specialized reader/player that interprets areas of light and dark on rotating disks made of lithographic film. The disks, which are interchangeable, are installed in a similar fashion to phonograph records on an ordinary audio disk player. Instead of a tone arm, the heart sound generator employs a fixed light source and a series of photo-electric cells to interpret the information contained on the disks. They contain representations of particular cardiac dysfunctions that are simulated on a sound amplifier as well as visually on a cathode-ray display. The device also contains a series of controls by which the operator can increase or decrease the volume of a particular sound track. In this manner, a student can be acquainted with a particular sound of a dysfunction that would otherwise be difficult to discern from the background sounds. The relationship between the sound of a particular condition and its electro-cardiogram (ECG) may also be established. A student may also gain experience in identifying and diagnosing particular dysfunctions, especially those that are not likely to be encountered readily in normal clinical practice. The simulator can also serve as a test unit to enable instructors to ascertain how well their students can differentiate both heart sounds and electro-cardiogram traces.

Although the heart sounds and the electronic trace are reproduced faithfully, reflecting a high degree of fidelity, the remainder of the simulator bears no resemblance to a human patient at all. The pedagogical premise employed is that the user is already familiar both with the rudiments of cardiac examination and with basic interpretation of heart sounds and traces, and that the only information to be learned from the simulator is the identification and recognition of particular dysfunctions. There is no need, therefore, for additional elements of the simulator to possess high-fidelity, since a medical practitioner should be able to transfer the knowledge gained on the simulator to a clinical setting. It may be argued further that by including other elements in such a simulator, the attention of the student will not be focused entirely upon the primary concept being presented. While there are usually many distractions in an actual clinical setting, the pedagogical approach of this type of simulator is to instruct the student in an environment free of non-essential distractions so that accurate discrimination of different murmurs can be made. Once the material is learned, it follows that the student will be able to diagnose particular cardiac dysfunctions while being able to contend with a number of distractions. Although this progression may seem logical, the efficacy of this method of instruction is not accepted universally (Gaba & DeAnda, 1987; Sandoval, Dale, Hendricson, & Alexander, 1987). In spite of such criticism, many simulators in medicine operate from the premise that to instruct effectively, the information to be learned should be presented without most of the accompanying stimuli in the process or procedure. As mentioned previously, there are simulators that consist of images and sounds generated or controlled entirely by computer.

Computer-generated and computer-controlled simulations

The adaptation of computers to teach new material or to assist with instruction became practical during the late 1950s (Rath, Anderson & Brainerd, 1959). While a valid pedagogical application of computers is simulation, they are also used for presenting instruction through other methods (see Chapter VII). The most common means, at present, by which a computer presents information to a human being in a comprehensible fashion is through a video monitor. Their ready availability, coupled with high costs of developing custom output devices, mean that most computer-based simulations employ output devices which, by their nature, possess a low degree of fidelity. This does not mean that such systems are inappropriate for medical education. In a manner similar to the heart sound generator, most computer-based simulations presume a given level of knowledge or competence in the area being instructed. A cardiology computer program, for example, may display a drawing of a patient on a video monitor and ask where one would place a stethoscope in order to best hear, "the effects of a mitral stenosis at the apex" (Rossall, 1974, p. 10). The design of the program assumes that the student knows what a stethoscope is and how to interpret the sounds it picks up. In this particular program, presented on the IBM 1500 system at the University of Alberta in Edmonton, the stethoscope in this part of the simulation consists of a light pen (see Chapter VII for a description). Responding to the placement of the light pen, the computer either indicates that the *stethoscope* has been placed in an inappropriate position, or it will cause a recording of the heart sound, as recorded in that location, to play (Rossall, 1974). The other end of the stethoscope is similar to actual examples. Sound is generated by a transducer that transforms electrical impulses into audible sound. With this arrangement, the user is acquainted and familiarized with particular heart sounds in the manner that he/she will encounter them in clinical practice. While the overall fidelity of this simulation is low, the activities and material to be learned, namely the correct placement of the stethoscope and the correct differentiation of various cardiac dysfunctions, possess high-fidelity.

While most students usually gain experience through clinical practice, it is possible that while learning and mastering particular skills, some patients might suffer discomfort and unnecessary injury. To avoid such problems, other types of simulators have been developed to enable the student to gain practice in performing particular manual procedures without either disturbing or imperiling live patients. Examples will be described in subsequent sections of this chapter.

Physiology simulators

While it is noted in previous sections that some simulators have been invented to permit practice that would not normally be available to students, other simulators have been developed to demonstrate physiological processes that are not readily visible. Campbell and Matthews (1968) state, "Attempts to understand physiology inevitably lead to the making of models; usually these are implicit, but sometimes they are explicit" (p. 249). In explaining and teaching particular dynamic aspects of physiology, it seems that a dynamic simulation of the aspect facilitates learning.

Crane, Yates and Steen (1968) state that before computers became available commercially, simulations of particular physiological systems and concepts was carried out largely using electronic components as analogies. For example, circuits containing capacitors and resistors were used to simulate particular quantities or concentrations of specific agents and their flow according to particular physiological systems (Crane, Yates & Steen, 1968). The authors note that these teaching aids possess serious pedagogical limitations, since they cannot demonstrate interrelated physiological events pertinent to anæsthesiology. Crane, Yates and Steen (1968) state further that the demonstration of how such events are interrelated might help teach individuals, "to administer current and future anæsthetic agents more safely and effectively" (p. 936).

To improve the versatility and efficacy of this type of teaching aid, a computer was substituted for the basic circuits. Containing resistors and operational amplifiers, this analogue computer could simulate dynamically, several physiological aspects occurring during anæsthesia simultaneously (Crane, Yates & Steen, 1968). The authors do not indicate either how the user interacts with the computer, or how the computer generates output. Although it is likely that this type of simulator was not manufactured commercially or used widely, this example illustrates both how simulators can demonstrate abstract concepts tangibly and how simulators may be used to address perceived pedagogical needs.

Digital computers have also been used to demonstrate concepts tangibly. Using an Elliot model 4100 digital computer and a new hypotheses based on established knowledge of respiratory variables such as blood flow, breathing rate and acidity of the blood, Campbell and Matthews (1968) programmed a simulation of the physiology of respiration. Once executed, the simulation program generates graphs of particular functions of respiration, listing the physiological factors likely responsible. It is contended that by comparing the findings of the simulation to clinical findings, it may be ascertained if the postulated hypothesis of respiratory physiology is valid. Campbell and Matthews (1968) state, "Failure of the model [simulation] to predict satisfactorily would, we hoped, indicate weakness in some of the assumptions and suggest further experimental work" (p. 249).

Although this particular simulation was not used to instruct in traditional ways, the simulation did provide feedback to the users about the validity of their hypothesis. The simulator functions as an instructional device, therefore. While Campbell and Matthews (1968) used their simulator for revealing the validity of a particular hypothesis, they contend that the simulation program can also be used by individuals for practicing diagnosis of particular conditions or diseases. Although clinical internship or regular duties enable physicians to practice diagnosis, human patients are usually unable to provide immediate feedback to the physician about the accuracy of the diagnosis made.

While it appears that the simulation program designed by Campbell and Matthews (1968) was not developed commercially, other medical educators designed computer-based simulations to provide students with opportunities to practice particular medical skills and procedures.

Interactive two-dimensional simulations

It is recognized that some medical educators use computers to present instruction in ways similar to those described in Chapter VII (McIntyre, 1980; Gravenstein, 1988). Some medical educators use two-dimensional, computer-controlled simulations to provide a transition between classroom instruction and clinical practice. Besides using *traditional* computer-controlled instructional methods, some medical educators use instructional devices that increase the fidelity of simulations by using specialized peripheral devices such as computer-indexed videotapes, videodiscs and voice-recognition input units.

Gas Man

Gaba and DeAnda (1987) state, "Mishaps during anesthesia remain a significant source of morbidity and mortality" (p. A467). This view is also shared by Gravenstein (1988) who notes, "in anesthesia, the patient suffers the consequences of mistakes made by the student" (p. 295). Although there is little likelihood that a student who is properly supervised will make a serious mistake, there is little to be gained by exposing a patient to such risk. Practice in administering anæsthesia appears to be likely means of reducing the incidents of clinical mishaps. As with training in CPR, practicing anæsthesia administration techniques upon live human beings is not encouraged because of the health risk to patients. Simulators overcome this limitation by providing practice with instructional feedback without harming actual patients. While the feedback may be extreme, such as an indication that the patient has expired, the user may learn from what was done without the guilt or anguish associated with the death of a human being. In this manner, it is anticipated that the user learns from the simulation, so that the same error is not repeated subsequently. The reduction or separation of emotion associated with particular actions is an aspect of some simulations that is not always perceived of as either valuable or desirable.

The humanistic psychologist, Carl Rogers claims that some simulations, specifically those that present nuclear war as some sort of game, diminish and trivialize the brutality and horror of nuclear war (Rogers, 1982). In a similar vein, Loftus and Loftus (1983) claim that many violent video games trivialize the gravity of violence, so that some individuals learn violent activities from such video games through observational learning (Bandura, 1965). While there is no evidence to suggest that student anæsthesiologists develop a callous disregard for the lives of patients by using simulators that mimic death of human beings, the concerns raised by Rogers (1982) and by Loftus and Loftus (1983) must be considered, since it is possible for unintended and unforeseen observational learning to occur through interaction with simulators.

One type of simulator designed to teach the principles of gaseous anæsthesia uptake and distribution without risk to human patients, is a commercial computer program named *Gas Man* (Philip, 1987). The program, written in Applesoft BASIC and compiled to Apple 6502 machine language, operates on an Apple Computer model II+ microcomputer, or compatible with at least 48 k Bytes of random access memory (RAM) and two game paddles. The program presents the concepts of the simulation, the educational objectives, the set-up procedure, then a sequence of simulated monitor displays followed by the results obtained by the user and instructive feedback. In a typical sequence, an anæsthesia monitor is generated on the screen with explanations of each gauge and measure. The student is then permitted to make modifications to it, based on suggestions made by the program (Philip, 1987). It is assumed that the user is aware that any modifications made to the monitor translates to a modification of anæsthesia distribution to the *patient*.

This two-dimensional simulation possesses high-fidelity only in the area of indicator interpretation and modification. Appearance of the patient and indicators associated with the actual appearance are missing entirely. The simulation is both dynamic and interactive, however, since subsequent actions of the simulation are dependent upon the actions of the user. To save time, the simulation runs eight times faster than normal. Philip (1987) contends that by interacting with the simulator, the user not only gains knowledge and practical experience interpreting gaseous anæsthetic monitors, but is also aware of some factors affecting the patient when particular elements of the anæsthesia are altered. While the low overall fidelity of the simulation and its accelerated speed may be seen as factors limiting the transfer of learning from the simulator, its low cost compared to more elaborate simulators may make Gas Man the only alternative to traditional methods of instruction and limited clinical practice.

Like many instructional devices mentioned in previous chapters, the commercial availability of Gas Man was dependent upon the perceptions of the market by manufacturers and publishers. Philip (1987) reports that individual copies could be obtained for $150.00 U.S. from Addison-Wesley publishers between 1984 and July 1985, when that company announced it was ceasing publication of materials related to medical education. Philip (1987) reports that by the end of publication, "Approximately 200 copies were sold in the USA and other countries" (p. 172). While the number of copies sold may seem low compared to popular software packages, it is important to note that few examples of more elaborate and more expensive simulators have sold as well.

ANSIM

The popularity and apparent effectiveness of Gas Man, prompted other individuals to create similar programs for other computer types. While Tanner, Angers, Van Ess and Ward (1986) note the existence of Gas Man, they state that the simulation will not operate on IBM-type personal computers. The authors designed a similar simulation program for such computers, taking advantage of the larger memory capacity of these computers. The program was written in Microsoft BASIC and compiled using the IBM BASIC compiler (Tanner, Angers, Van Ess & Ward, 1986). Using physiologic models that are accepted widely within the medical profession, the authors designed their simulation, called *ANSIM*, to include more variables and displays to the effects of more anæsthetic gases than were available with Gas Man. The speed of ANSIM may also be varied. In its slowest mode, ANSIM operates three times faster than real time. To show long-term effects quickly, possibly to induce the user to react to situations quickly, ANSIM can be accelerated to function 30 times faster than real time. No reason is given why ANSIM cannot proceed in real time.

Although Tanner, Angers, Van Ess and Ward (1986) claim that ANSIM is a successful anæsthesia simulation for instruction, they do not mention whether the program was made available commercially like Gas Man. It is likely that many of the factors noted in Chapter VII as affecting the deployment of computers as instructional devices, also affect computer-based simulations. In spite of the claimed success of Gas Man and ANSIM, the efficacy and the validity of such two-dimensional simulators with overall low-fidelity continues to be criticized by some medical educators (Gaba & DeAnda, 1987). Other medical educators have designed two-dimensional simulators with higher fidelity overall, contending that such efforts improve the transfer of learning from the classroom to the clinical setting.

CAVI

Sandoval, Dale, Hendricson and Alexander (1987) describe a two-dimensional, dynamic/interactive video-based simulator, called *CAVI*, an acronym for *Computer-Assisted Video Interactive simulation*. Used primarily for instruction in endodontic treatment procedures, the equipment consists of a videotape player connected to an Apple model IIe computer equipped with a videocassette recorder (VCR) interface board. While it might at first seem that this apparatus functions like some computer-controlled instructional devices described in Chapter VII, the CAVI is not used to present instruction to the student initially. Instead, the student is shown a hypothetical patient who describes symptoms and conditions, and shows their external effects where applicable. At several points, the simulation is halted while the student enters diagnostic observations and/or decisions about treatment. Once the sequence of diagnoses is complete, the computer indicates the score obtained and then permits the student to review any part of the simulation (Sandoval, Dale, Hendricson & Alexander, 1987). While it might appear that this simulation is at odds with many principles of instruction provided by computer, as described in Chapter VII, since feedback is provided only at the end of the sequence, it is important to note that a dentist is not stopped and corrected in practice as errors are made in an actual diagnosis. By presenting the simulation in this manner, the fidelity of a simulated patient/dentist interview is kept to a high level.

To ascertain the pedagogical effectiveness of this type of simulation, Sandoval, Dale, Hendricson and Alexander (1987) conducted an experimental study comparing the error rates made in responding to diagnostic questions between seven experimental groups receiving instruction from particular instructional devices, and a control group which received traditional classroom instruction. The first experimental group received a slide-tape presentation followed by an examination. The second group also received the slide-tape presentation, but the questions were presented in a book also containing information printed with invisible chemical ink. When a particular response is selected by the student, immediate feedback can be obtained by dragging a special felt-tipped pen across the area of the page next to the selection. A correct selection reveals confirmation that the choice is correct (positive feedback) while an incorrect response reveals an explanation of why the response is incorrect. This apparatus functions like several of the invisible chemical ink-based teaching machines described in Chapter VI. The third group also received the slide-tape presentation, but the questions were presented by a computer. Evaluating the selections made, the computer also provided feedback in a manner similar to the invisible ink books. The fourth group saw the slide-tape presentation followed by a session with the CAVI. The fifth group were given the invisible ink books only. The sixth group undertook the computer examination only, and the seventh group worked with CAVI only (Sandoval, Dale, Hendricson & Alexander, 1987).

Although the study did not reveal any significant differences in error rates among the eight groups, it is noted that in particular aspects some groups performed significantly better than the others. Sandoval, Dale, Hendricson and Alexander (1987) also note that the group receiving the slide-tape presentation and a session with the CAVI, "had the lowest overall frequency of errors" (p. 535). This result is attributed to the contention that, "More peripheral information was probably conveyed through simulation formats such as CAVI, where visual effects could be maximized" (Sandoval, Dale, Hendricson & Alexander, 1987, p. 536). In other words, the higher fidelity of the simulator compared with the other instructional devices used, is the main factor contributing to the greater effectiveness of the CAVI. It is also important to note that different instructional devices used in combination resulted in a lower error rate than instruction by any individual instructional device in the study used singly. While the apparent success of the CAVI simulator might seem to make it a desirable instructional device, the authors note that materials for it were more expensive to prepare than for any other instructional device mental time for a CAVI module was nearly three times that of the slide-tape program" (p. 536). Although it seems that CAVI was not developed commercially, other medical educators designed even more elaborate simulators in spite of high cost both for equipment and preparation time.

Voice-activated two-dimensional simulator

Harless, Zier and Duncan (1986) designed a computer-controlled simulator that uses a videodisc and voice recognition response entry for instruction in clinical medicine. The computer uses the videodisc to present discrete image sequences quickly, a feature not available with most videotape machines. Harless, Zier and Duncan (1986) state, "the interactive videodisc allows believable dramatization of the medical situation" (p. 913). The authors state that the apparatus is designed to be used by an instructor in the presence of a class. The ostensible reason given for not accommodating individualized instruction is that using the system as a class-based adjunct to instruction, "allows spontaneous class discussion about the content of the case and provides the instructor with context for making cogent points and teaching relevant concepts" (Harless, Zier & Duncan, 1986, p. 913). It will be shown later how this explanation is at variance with the learning theory thought to underlie this simulator. A likely reason why the authors abandoned an individualized instructional approach are the technical limitations of the voice-recognition circuitry.

Harless, Zier and Duncan (1986) note that the voice-recognition unit requires approximately 30 minutes to *learn* to recognize a vocabulary of 135 words spoken by a specific individual, and that this activity is undertaken by the instructor. Following this recognition training, the voice-recognition unit is able to recognize spoken words congruent with words in its vocabulary with accuracy, "greater than 95 percent" (p. 914). While the voice-recognition unit may recognize the words spoken by the instructor, it may not recognize the words when spoken by other individuals given differences in pronunciation, accent, pitch and modulation. It seems likely, therefore, that this limitation of the voice-recognition unit contributed to the authors' endorsement of a class instructional approach.

In operation, the computer causes images and sounds of an actual patient to be displayed on the monitor. After showing the patient entering an emergency ward and being interviewed by a nurse, the image is frozen. Without any prompting by the computer, the instructor, in consultation with the class, either asks questions for additional information, or states what action is to be taken next. Asking a question launches a dialogue between the instructor and the patient in the simulation. The voice-recognition unit translates the instructor's words into digital signals that are analyzed and interpreted by the computer. Assuming that the interpretation is done correctly, an appropriate sequence is retrieved from the videodisc and is played on the monitor. If the requested information is not present, then a sequence is played where the patient states, "I don't know" (Harless, Zier & Duncan, 1986, p. 914). Aspects of a physical examination can also be requested, including X-ray images, physiological sounds and the results of particular tests.

Like some instructional devices invented by Gordon Pask (see Chapter VII) the voice-activated simulator employs a ***probability algorithm*** to select the direction of the simulation. This approach differs from other instructional devices especially most behavioristically-based teaching machines that either follow a set path through the lesson, or select one of several possible choices at each decision point. While Harless, Zier and Duncan (1986) do not use the term *fuzzy operations* or *fuzzy logic* to describe the operation of their probability algorithm, it functions in a manner similar to Pask's algorithms. The progress of the simulation is in part determined by the accuracy of previous decisions made by the user. Harless, Zier and Duncan (1986) report that probability values in the algorithm are altered positively by the user asking relevant questions in a logical se-the user to predict the next step, although it is noted that the simulation is capable of providing only three possible conclusions to the diagnosis session. The authors contend, nevertheless, that the feature of unpredictability in the progress of the simulation, "provides a lifelike mystery in the case study and offers an opportunity for learning by discovery in the classroom" (Harless, Zier & Duncan, 1986, p. 914).

While the authors contend that the theory of learning embodied in this simulation is *learning by discovery*, their understanding of the theory is at variance with the definitions provided by Bruner (1961) and Ausubel (1962). Both contend that *discovery learning* involves the individual student interacting with appropriate materials individually in an environment encouraging exploration and discovery. While this approach may be used with the simulator created by Harless, Zier and Duncan (1986) it is impractical, given the technical limitation imposed by the voice-recognition unit. It seems, in this instance, that the design of an instructional device is not determined by theories of learning or instruction, but by the limitations of the technology used.

Harless, Zier and Duncan (1986) state that their voice-recognition interactive videodisc-based simulator is experimental and that further testing of the system will be undertaken before attempts are made to produce commercial versions. While it is likely that individual students in classes do learn something from two-dimensional interactive simulators of this variety, an inability to provide individualized opportunity to practice diagnosis may be seen by some medical educators as a serious limitation of this type of simulator. While the fidelity of this simulator is much higher than a slide-tape presentation, since the user can interact dynamically with the simulation, there is no provision in the design of such simulators to permit practice with *hands-on* physical examinations. In this respect, most two-dimensional simulators possess low fidelity. Addressing this limitation of most two-dimensional simulators, other medical educators have devised hybrid simulators that combine elements of two-dimensional simulation with three-dimensional simulators.

Hybrid simulation systems

Some manikin-based simulators have been described in previous sections. While most simulators of this type are equipped with simple feedback mechanisms, some may be connected to computers, so that more complex medical conditions can be presented and analyzed. For example, Gaba and DeAnda (1987) have connected an intubation and bronchoscopy simulator with inflatable lungs to an elaborate computer-controlled simulation system for teaching anæsthesia procedures.

Besides the intubation/bronchoscopy simulator, the system contains an actual urine measurement bag connected to a vessel containing a dye solution. Movement of the solution from the vessel to the bag is controlled by the computer. The main computer, a Compaq Plus microcomputer, controls aspects of the manikins, the urine simulator and two electronic simulator units, through serial port connections (Gaba & DeAnda, 1987). These two units generate cardiac data and information about the type and amount of dissolved gases in the blood respectively The cardiac data are displayed on an actual monitor system, while information about gas levels in the blood appears on the screen of a Macintosh Plus microcomputer. While the entire simulation system is under the supervision of an actual anæsthesiologist, who obtains a script and supplementary information by a second Macintosh Plus microcomputer, an operator controls the operation of the main computer (Gaba & DeAnda, 1987). Except for the manikins, urine bag, and the data displays, the remainder of the apparatus is obscured from the view of the user. The simulation proceeds in the manner of an actual operation, likely in real time. The obscured anæsthesiologist causes problems in the simulation that require the intervention of the user. Criteria for acceptable procedures are provided to the supervising

Although this simulator possesses high-fidelity in only some physical attributes of a patient, Gaba and DeAnda (1987) note that this type of simulation is an improvement over most previous endeavors that either do not present most of the variables to be monitored, or which present the simulation solely as a two-dimensional video display that cannot permit the user to demonstrate or to practice specific physical procedural techniques. This shift from two-dimensional to three-dimensional representation, and to a higher level of fidelity overall, reflects the pedagogical view that by replicating actual conditions as closely as possible, a greater transfer of learning will occur from the simulation to the actual situation. This premise is likely the primary reason why simulators with overall high-fidelity have been devised for aspects of medical education.

Sim One

Constructed during the late 1960s and referred to as *Sim One*, this simulator combines the technology of medical manikins, sophisticated computer input devices and specialized output devices with the extensive control afforded by a computer, to produce a system with a higher degree of fidelity overall than previous simulators. Sim One consists of a plastic-skinned manikin body intended to represent an adult male of indeterminate age with a height of six feet and a weight of 195 pounds (Denson & Abrahamson, 1969). Unlike manikins designed for resuscitation training, that possess high-fidelity in only a few aspects, Sim One is similar to an actual patient in many ways. Besides possessing a heart beat, pulse and blood pressure, Sim One also: breathes, exhibits particular muscle spasms and motions of the upper body, opens and closes its mouth and eye lids, exhibits pupillary changes, vomits on command and can inhale or receive injections of anæsthetics to which it will react (Denson & Abrahamson, 1969). The simulation, which operates in real time, was designed primarily for teaching techniques of anæsthesiology. A computer interprets the actions of the student on the manikin by means of subcutaneous sensors, specialized input devices. For example, microswitches located directly above the teeth in the upper jaw of Sim One, detect a particular mistake in intubation. Should excessive pressure be brought to bear on the upper front incisors, then a microswitch is closed, sending a signal to the computer. The computer identifies and interprets the signal and then causes solenoids attached to the incisors to be energized. This action causes the incisors to *pop-out* of the manikin's jaw (Denson & Abrahamson, 1969, pp. 505-506). Similarly, sensors within the lungs of the manikin sense and analyze the types and quantities of anæsthetic gases administered. An improper administration may result in particular solenoids being activated by the computer. These solenoids cause portions of the manikin to move, thus simulating muscular reactions to the improper administration. When correct procedures are followed, the manikin reacts in what is considered a normal fashion; the eye lids close and *muscles* relax. Severe errors in selection or administration of anæsthesia may result in an emulation of death, where the vital signs cease and the pupils of the eyes dilate.

At least one study has been made concerning the efficacy of Sim One versus internship instruction. Abrahamson, Denson, and Wolf (1969) find the effectiveness of Sim One only slightly higher statistically than conventional methods of instruction. The major advantage noted is that a student will learn the required skills in a shorter time interval than if he/she was instructed through existing methods. It is also likely that using a simulator with high-fidelity overall facilitates the transfer of learning from the classroom to the clinical setting. The use of such simulators also ensures that each student receives both exposure to and practice in those conditions and procedures that are considered important before being permitted to practice upon real patients. The success of creating a medical simulator with a high degree of fidelity overall prompted other medical educators to embark on similar work.

Harvey

Beginning in the late 1960s and based somewhat upon the design of Sim One, Gordon (1974) describes the development of a manikin-based device more complex than Sim One, that can simulate most conditions and symptoms exhibited by patients with cardiologic disorders. A prototype of the new simulator was completed in 1976 (Gordon, Ewy, DeLeon, Waugh, Felner, Forkner, Gessner, Mayer & Patterson, 1980). Called *Harvey* after the physician W. Proctor Harvey, the device incorporates features not present in Sim One, such as the greying of the hair and skin cyanosis (Gordon, 1974). It was intended that Sim One possess cyanosis initially, but constraints imposed by time and existing technology precluded this feature (Denson & Abrahamson, 1969). Through the use of computer-controlled multi-tracked recording tapes, a small radio transmitter, stethoscopes modified to receive broadcast radio signals selectively and special sensors positioned strategically within the manikin to activate the reception of the stethoscope, normal heart sounds as well as up to 50 abnormal sounds can be simulated (Gordon, 1974). By increasing the overall fidelity of the simulator to the highest level possible with the technology available, certain disease conditions that are associated with particular age groups can be reproduced with great accuracy. By having the manikin emulate an older person with grey hair, for example, it is possible to reproduce the symptoms and the effects of a stroke in a realistic manner. This feature is important in encouraging the student to consider all possible factors when making a diagnosis. Simulating a person of indeterminate age, such as was done by Sim One, denies the user several physical cues that may facilitate a speedy and accurate diagnosis.

It may be contended that high-fidelity simulators have many advantages for instruction over the use of live patients. Such advantages include: no risk of death; the presentation of rare diseases and conditions that might not normally be encountered by a medical student; procedures can be halted and repeated; traumas can be simulated in real time, or they can be slowed down for closer study (Gordon, 1974). A study comparing skill levels of cardiology students trained by Harvey with students trained by traditional methods reveals that students trained on Harvey achieved significantly higher scores (Ewy, Felner, Juul, Mayer, Sajid & Waugh, 1987). In pedagogical terms, high-fidelity simulators more so than simulators with lower fidelity, such as depicting the patient on a video monitor, force students to interact with the material being learned in psychomotor as well as in cognitive ways. Such three-dimensional high-fidelity simulators eliminate most of the problems noted with the transfer of learning from the theoretical to the practical. Another advantage of such high-fidelity, three-dimensional simulators, is that they may provide a convenient opportunity to practicing physicians to keep up with new techniques in diagnosis and treatment by learning and practicing. Perhaps the most important advantage of using this type of high-fidelity simulator is that it tends to ensure a standard level of instruction that might be lacking if a student received clinical experience only (Gordon, et al., 1980).

There are factors that diminish the appeal of high-fidelity simulators. A major one is cost. It may be argued that a high initial capital cost is justified given the large number of students that the apparatus can train before it either wears out or becomes obsolete (Gordon, 1974). Some medical institutions, however, may not be able to raise sufficient capital to purchase a high-fidelity simulator in the first place. Failure of the apparatus and maintenance costs are additional cost-related disadvantages. This variety of three-dimensional high-fidelity patient simulators are generally scarce in medicine, so availability of parts and competent service may prove to be difficult and expensive. Also, the use of a high-fidelity simulator does not eliminate the need for live patients for student practice, since an interactive clinical component is usually considered essential in most tals (Gordon, et al., 1980). Another concern is whether the device actually embodies conditions and diseases that are widely important for the doctors being trained, or whether the simulator reflects a local bias towards particular conditions and diseases (Gordon, 1974). Although the disadvantages of simulators may induce some medical institutions to not use them, a high demand for new physicians coupled with rapidly-changing treatment techniques that must be learned quickly by practicing physicians, may result in an acute need for such instructional devices.

Conclusions

Simulators have had minimal rôles in medical education throughout most of its history. While technological limitations appear to be the most significant factor accounting for their sparse use, particular social considerations required the development of alternate methods of pedagogy to those in use. From the examples described previously, it is apparent that the application of simulators to this field have been valid and effective. In most instances, the pedagogical foundations of these devices is sound, although the variability of fidelity may determine the extent to which a particular device is effective in facilitating a transfer of learning. It appears, however, that it is perceived need that determines whether a simulator will be used and accepted by physicians. In the case of obstetrical training for example, simulators arose from a perceived need for a satisfactory training method to contend with an immediate need for competent midwives. Given the developments in the technology of simulators within the last 25 years, it is possible that their use will increase in future, should perceived needs develop to teach concepts and procedures to large numbers of individuals at set times. Although factors such as cost may restrict the use of some high-fidelity simulators, other factors such as instructional efficacy and the satisfaction of an immediate need should not be overlooked. While the use of various types of simulators in medical education appears to have increased and developed since the seventeenth century A.D., other fields of instruction have either been slower to adopt the use of simulators, or simulators have been used for specific periods and then discontinued.

Simulation games for instruction

Although the previous sections show how it is possible to consider simulators from the perspective of discrete subject areas, this approach is inappropriate when describing other types of simulators, since many were devised for one purpose or subject area and then adopted for use in other areas. It is for this reason that subsequent discussion of simulators will be based on classes of apparatus rather than on subject areas.

It is noted previously that one of the most long-lived simulators is the quintain (see Chapter II). Changes in military technology is cited as the most likely reason for the abandonment of the quintain as a simulator used as a military teaching machine (see Chapter III). To be sure, simulated weapons have been used by recruits either for safety reasons or because actual examples of the weapons were not available. Within this century, many recruits receiving instruction in the proper use of the bayonet obtained practice by attacking simulated enemies in the form of stuffed canvas or burlap sacks suspended from a frame. While this arrangement may seem similar to the quintain, a bayonet practice dummy is more like the palus, since both are largely incapable of providing any instructive feedback. Most bayonet practice dummies, therefore, possess a lower degree of fidelity overall than the quintain. In a different sense, it may be contended that this type of simulation is less effective pedagogically than one which requires input (interaction) from the user.

own simulators. Instead, they usually adopted simulators designed for other purposes. In many instances, military organizations began using particular simulators only after their efficacy was proven in other areas of instruction. Some of the earliest examples of this phenomenon are games.

Games that simulate abstract concepts

Although it is not known when games were first devised, Taylor and Walford (1978) note the existence of some in China as early as 3,000 B.C. Several of these early games appear to simulate aspects of abstract military strategy in tangible ways, since the object of these games appears to be for one player to encircle his/her opponent. Whether these games were recognized at that time as simulating military strategy, or whether this interpretation is a function of modern study is not known. It is known that Chess, which Taylor and Walford (1978) contend is derived from these earlier *encirclement games*, was used beginning in the mediæval period as a simulation of battles where individuals could experiment with and practice elements of military strategy, tactics and logical planning (Ellison & Coty, 1987). Unlike the quintain, which simulates an actual object and event through the omission of elements of reality, Chess attempts to provide a concrete and dynamic means by which individuals can transform their abstract concepts into something tangible. This view is shared by Naylor, Balintfy, Burdick and Chu (1966) who state, "Military gaming is essentially a training device for military leaders which enables them to test the effects of alternative strategies under simulated war conditions" (p. 3). Games in general are described by Bruner (1967) as analogies either of theories or of reality.

While it might appear that Chess is a crude simulation of a battle, the game possesses a high degree of fidelity in simulating the effects of and difficulties in applying abstract strategy to a concrete situation. The low fidelity of personnel and the actual battle are likely advantageous in this simulation, since these elements are largely irrelevant when considering the transformation of abstract strategy into concrete battle plans and manœuvres.

Ellison and Coty (1987) contend that the use of Chess as a military instructional simulation was so successful that its use prevailed until the nineteenth century when is was superseded by other games with increased fidelity in particular aspects. One example is the Prussian game *Neue Kriegsspiel* [new war game]. Although the principle of the game is similar to Chess, simulated terrain, models of artillery pieces and soldiers are used instead of the lower fidelity chess board and symbolic pieces (Ellison & Coty, 1987).

Playing military games of the sort that permit the concrete simulation of abstract ideas and strategies may result in the development and establishment of new strategies likely to be successful in the field. Some historical evidence supports this contention. Taylor and Walford (1978) claim that the *Schlieffen Plan* used with initial success by the German Army in the First World War, was developed by trying and modifying strategies in war games prior to the outbreak of hostilities in 1914. While the Schlieffen Plan at first seemed to prove that abstract strategies simulated in a war game could be transferred into practice with identical results, most war game simulations either omit particular elements, or their fidelity is too low to have a decisive effect on the actual situation. The advent of trench warfare combined with extreme wet weather and tactical errors resulted in the failure of Schlieffen Plan to achieve the same goals in the field as it had done in the simulation game.

The apparent success of particular war games in developing effective new strategies that could be transferred successfully to the field likely encouraged military organizations in other countries to adopt the use of such simulation games. Ellison and Coty (1987) report that war game simulations did become popular with most military organizations in the twentieth century. The authors note that the importance placed on simulation games by the United States Army is apparently high, given that a 1.5 million dollar war-gaming centre was opened in 1983. By using such simulation games to teach or to develop strategy, errors in replicating known strategies may be identified, noted and corrected immediately, arguably a preferable pedagogical strategy to losing a battle or manœuvre and then trying to ascertain the causes of the loss at a time far removed from the actions. It is also important to note that the cost of simulation games is usually much less than actual manœuvres or battles.

While some military organizations have made simulation games an integral part of their education programs, Taylor and Walford (1978) note that these types of games continue to be forms of entertainment for the general public and that they are, "usually played these days with no ulterior motive" (p. 4). This example shows how particular simulations and simulators may not necessarily be devised or used solely within one discipline, group or domain.

Other games that simulate abstract concepts in tangible ways, devised initially for entertainment, have also been adapted to instructional uses. Taylor and Walford (1978) note that *Monopoly* can be considered a simulation, "because of its basic representation of real life with a simple 'model'" (p. 3). The author's interpretation of the simulation seems inaccurate, however, since few lives resemble a Monopoly game. It is more plausible to consider Monopoly and similar games to be simulations of abstract concepts such as financial risk taking or a market economy; the effects of which may interact with real lives. The concepts themselves, however, do not exist except as similar representations in the minds of individuals. In this way, Monopoly may be used as a simulation for instructing the principles and factors inherent in capitalism. As noted previously, there is no consensus on the definition of terms or defining whether a particular activity or event constitutes a simulation or not. It is for this reason that Alessi and Trollip (1985) describe Monopoly as an *instructional game* rather than a simulation. One difficulty in making such a distinction between simulators and instructional games is that many games subsumed under the description *instructional games* simulate either actual occurrences or abstract ideas. For example, a game showing a drawing of a cannon and the trajectories of cannonballs fired from it may be classified as an instructional game, yet it is a simulation of an actual event, even though the simulation may be two-dimensional with low fidelity overall and act slower than real time. Instructional games, therefore, are considered simulations in this treatment.

Ellison and Coty (1987) state that by the 1950s several disciplines became interested in using simulation games as instructional devices. For instruction in political science, for example, the Rand Corporation devised *crisis games* that may be set up to simulate actual or possible international conflicts (Ellison & Coty, 1987). While this type of simulation reflects the tangible manifestation of abstract ideas rather than a simplification of reality, these simulators provide policy makers opportunities to try out tactics and strategies to experience possible outcomes. Predictability of moves or outcomes is modulated in such games by requiring the use of dice, thus ensuring a stochastic element in the simulation. While the action of rolling dice is unrelated to the simulation and may be considered as diminishing fidelity, the use of dice actually increases the fidelity of the simulation by simulating the stochastic nature of the actual situation. The effect of random or unforeseen events in actual situations occurs usually because all of the factors and variables are either not known or are predicted inaccurately.

It may be contended that through practice with such simulations, experiences gained are transferred to actual situations, so that the performance of the policy makers are likely to be superior to their opponents, provided that the opponents have not received similar education from such simulations. Although a lack of a convenient method of scientific analysis makes it practically impossible to establish the validity of this contention, the apparent success of similar simulations for military education suggests that other simulation games are likely to be successful as well.

Some businesses and industries also began using game simulations for training and education beginning in the 1950s (Ellison & Coty, 1987). Besides Monopoly, specialized games exist to provide practice and experience to individuals in these areas. One example is a game simulating labour/management negotiation called *Settle or Strike*. Although the game is played on a plastic sheet and the small plastic pieces representing individuals and corporations possess extremely low three-dimensional fidelity compared with actual individuals, the principles and experiences learned in the game may be transferred to actual labour/management negotiations. The development and use of business simulation games has not been restricted to North America. Gilligan (1975) reports that simulation games for various business types were in use and being developed in the United Kingdom before 1970.

Rôle-playing

The instructional efficacy and the popularity of games simulating military actions and events likely encouraged other educators to use similar instructional methods. The use of games as instructional devices are noted in Chapters IV and V. While most examples noted are not simulators according to the definitions in this chapter, games that involve rôle-playing such as some devised by Erasmus, Locke and Wilderspin, may be considered simulations. Some researchers such as Kohlberg (1971) Fines and Verrier (1974) and Erikson (1977) contend that there is a natural tendency among children to simulate the behavior of others as a means of learning about and understanding their own behavior and personality. While this form of simulation may be self-instructional, other researchers maintain that such a self-discovery approach may not be present in all individuals. Instead, such researchers advocate structured rôle-playing simulation games where the individual is obliged to simulate attributes or behavior of a specific person or being. Taylor and Walford (1978) state that with this method, "it is hoped that pupils gain a greater understanding of other roles and relationships, as well as a better awareness of what they themselves are doing" (p. 9). Moreover, the authors note that rôle-playing appears to be an effective method of instructing adults in particular social behaviors. As an example, rôle-playing might be used as a method of teaching socially-acceptable tolerance of visible minorities. This same approach might also result in learning as defined by behaviorism, since rôle-playing may be used to extinguish particular behaviors considered racist or intolerant. Rôle-playing is also used by some psychological counselors to learn circumstances or details of events that are either too painful for individuals to recount, or which are beyond their verbal capabilities (Chaplin, 1985).

It might at first appear that since rôle-playing entails imitation, it is either observational learning as described by Bandura (1965) or social learning as described by Miller and Dollard (1941). While the basis of rôle-playing is imitation, the motivation behind rôle-playing in an instructional setting is different from imitation. Instead of imitating particular behavior to gain attention or acceptability from a group, rôle-playing usually entails a conscious analysis of the behavior to be imitated. It is the analysis of the behavior, not the imitation or simulation of it that is important in rôle-playing. Such analysis, in turn, may result in the rôle-player learning something about why the behaviors he/she is imitating or simulating, are emitted by the rôle model in the first place.

To this point, most of the simulation games described require the participation of two or more individuals. The nature of such simulations prevent them from being used for individual instruction. It may be argued that individualized instruction in many instances is inappropriate because it reduces the element of competition with other human beings, an element present in many actual situations, including those pitting one abstract thought against another. One problem with Chess games and other simulation games requiring several individuals, is that usually one or more individuals is a loser. Also, the nature of such simulations prevent them from isolating and presenting factors and possible reasons why these individuals lost. Conversely, the winner may not always be aware of the specific combination of factors contributing to the win. By presenting a simulation to a single individual and also presenting instructive feedback to that individual when errors in logic, procedure or perception are made, it may be contended that greater *meaningful* learning will occur, while maintaining the element of competition. In such instances, competition is provided by the mechanism controlling the simulation rather than by another individual. In the manner of Pask's adaptive machines (see Chapter VII) some simulators may be designed to provide varying degrees of challenge and difficulty to the user.

Computer-controlled simulation games

While some mechanical devices may be able to control the operation of a dynamic/ interactive simulation, including analysis of user input and the presentation of appropriate instructive feedback, computers have proven to be more adept at performing these actions. Recalling the description of the Whirlwind project in chapter VII, computer technology was not developed sufficiently to control simulations until after the Second World War, a view shared by Naylor, Balintfy, Burdick and Chu (1966). While computers were first used to control three-dimensional, high-fidelity, dynamic/interactive simulations of actual mechanisms and situations, computers have been used subsequently both to control and to present simulation games for individualized instruction.

Computer-controlled Chess games exist for entertainment, but particular models may also be used to teach individuals the fundamentals of the game as well as particular logical strategies. Similarly, many of the games mentioned in previous sections can also be presented by computer either in ways similar to the original, or the computer can alter the progression and/or speed of the simulation. Gilligan (1975) reports that computer-controlled versions of business simulation games were developed because non-computerized versions lacked sufficiently high situational fidelity. "The consequent lack of realism encouraged the students to focus on the 'game' aspects of the situation and little or no understanding of business decision-making emerged" (p. 32).

While most computers present such games in two dimensions rather than three, the fidelity of other attributes may be increased because of the capabilities of computers and peripheral devices. In a business simulation game called *Lemonade Stand*, for example, a computer's CRT display is used to show a drawing of a typical lemonade stand as constructed by a child, complete with a pitcher of lemonade and glasses. Once the price is set on the basis of factors such as the cost of materials, other factors such as weather conditions are noted and the simulation of sales for a day proceeds many times faster than real time. As glasses of lemonade are sold, the level of lemonade in the pitcher falls while a stack of coins rises. In this way, the simulation shows iconically, the relationship between the sale of goods and income.

Other instructional game simulations, such as *Decimal Darts*, are intended to increase motivation in the learner (Alessi & Trollip, 1985). This simulation presents a two-dimensional side view of a target containing several balloons. Several numbers are placed behind the target. Drawings of darts are shown opposite the target. The object of the game is for the user to estimate the position of the balloons relative to the numbered scale and send darts to that position. A successful estimate results in the dart rupturing the balloon. Some versions of a similar game also simulate the sound of an exploding balloon simultaneously with the image of the dart rupturing the balloon. An inaccurate estimate results in the dart sticking into the target at that point. It is contended that by observing whether the dart is above or below the balloon, the user will adjust the numbers entered, so that subsequent dart throws will be successful in striking balloons. Not only does this game simulate aspects of dart throwing, but it attempts to teach the learner concepts of scale and estimation by showing these concepts iconically. While the darts and balloons simulate actual items, the concept of numeric scales is mathematical and largely abstract. This game, therefore, embodies simulations both of actual objects and of abstract concepts.

Other types of instructional game simulations are mentioned in chapter VII. Dedicated devices such as Speak & Spell simulate a few aspects of a teacher with a high degree of fidelity. Besides simulating the verbal feedback usually provided by teachers, the device also combines verbal information with printed letters and words. It is likely that this strategy is intended to encourage the user to associate particular sounds with the printed letters and words, a pedagogical strategy used by some actual teachers.

As noted in previous sections and chapters, motivating the student to use particular instructional devices is a perennial concern to educators and the designers of instructional devices. Another strategy for increasing the motivation of instructional devices, which is used by educators occasionally, is to adopt motivational methods inherent in commercial devices. When the novelty of using such devices diminishes, then other methods of motivation are sought. It is noted in Chapter VII that Seymour Papert was hired by the Nintendo Company to investigate the possibility of incorporating principles of popular video games into instructional materials to make them more motivating for student use. Papert (in Stecklow, 1990) claims that the reasons for the popularity of many video games is not obvious *prima fascie* and the matter requires extensive research. While the current popularity of particular computer-controlled video games, both those designed for personal home use and those designed for game *arcades* cannot be disputed, possible reasons for their popularity may be incongruent with methods of pedagogy considered appropriate by most educators and parents.

Many computer-controlled video games are elaborate simulations of actual events or tangible representations of imaginary events. Using current video and computer technologies, pseudo three-dimensional visual simulations can be created including appropriate sounds and speeds. Besides these attributes, a high level of interaction with the user is a common characteristic of such simulation games. In many instances, such games simulate violent acts and they usually require the user to interact with the game using simulated lethal weapons such as guns and cannons to kill an enemy or to annihilate a geographical location. It may be that an elevated level of excitement caused by the depiction of violence or through violent interaction functions as a strong motivator to the user to continue playing the game.

Examples of simpler computer-controlled simulation games designed solely for use in classrooms, such as some designed for the PLATO system also simulate acts of violence, ostensibly to maintain user interest and to sustain motivation. Alessi and Trollip (1985) describe a PLATO spelling and word guessing simulation game called *Ordeal of the Hangman*. Incorrect entries cause the computer to draw progressive portions of an individual on a scaffold prepared to be hanged. Guessing the word and spelling it correctly prevents the execution of the individual. If incorrect entries continue, however, a hangman causes a trap door to open, resulting in the hanging of the individual on the scaffold. After falling to the end of the rope's travel, the executed individual sticks out its tongue and a balloon containing the word *gag* is displayed next to the head (Alessi & Trollip, 1985). These actions are supposed to indicate to the user that he/has lost and that the game is over. Although the simulation is two-dimensional and the execution possesses low fidelity overall, there is a danger nevertheless, that the user may learn to tolerate the depiction of violent acts and/or become desensitized to them. Moreover, following the principles of observational learning as described by Bandura (1965) it is also possible that the user will model the simulated behavior in real life subsequently. Similar views are expressed by Rogers (1982), Zimbardo (1982) and Loftus and Loftus (1983).

Some computer-controlled simulation games consist of a high-fidelity, three-dimensional interaction that is transformed by computer into two-dimensional feedback. An example is a simulated golf course. Although golf is a popular game, many individuals strive to learn more effective techniques and to improve their skills generally. While playing and practicing golf usually maintains a particular level of performance, or results in improved playing of the game, climates in parts of the world prevent both the playing and practicing of golf for protracted times during the year. Enclosed driving ranges permit some practice in a controlled climate, but a large enclosed area is required for such facilities. As well, such facilities possess low fidelity as compared to actual golf courses, so it is debatable as to how much information learned from driving ranges can be transferred to an actual golf course. Simulated golf courses usually occupy less space while still permitting practice.

Most of these simulators consist of a projection screen where a film or video image is displayed. A fine mesh is supported in front of the screen. The mesh is attached to sensors that can measure the degree of pressure applied to it and the coördinates of the pressure. Information from the sensors is sent to a computer that also controls an image projection device. For practice, an image of a portion of a golf course is displayed. The golfer, standing a set distance away from the projection screen and mesh, tees up and drives the ball. The force and position of the golf ball against the mesh are interpreted by the computer and a moving image sequence approximating the course of the ball along the fairway and green is projected. In this way, the golfer obtains instructive feedback on the strength and direction of his/her drive. Besides being able to practice in a pleasant environment, golf simulators possess a higher degree of fidelity overall than most driving ranges.

While this section shows how particular simulations designed as entertainment can also be used for instruction, there are simulators constructed in the twentieth century designed primarily for instruction. Many of these simulators have also been used for entertainment purposes as well.

Simulators for teaching procedures and motor processes

Flight simulators

In the twentieth century, one of the first areas where simulations of actual objects or events were developed and used in response to a perceived need was flight training. It was realized by some individuals, soon after the availability of powered aircraft for commercial use, that learning to fly in an environment innocuous both to flyers and equipment was highly desirable, likely as the result of the loss of many lives and aircraft. Haward (1910) states that one of the greatest risks in learning to fly, "especially to those not blessed with a long purse, is the risk of smashing the machine while endeavoring to learn how to control and fly it" (p. 1006). To alleviate equipment costs and some of the dangers in learning to fly, several simulators were designed to provide initial training to aspiring aviators. Although it is difficult to establish which particular simulator was invented first, it seems that the first examples appeared four or five years after the Wright brothers' initial flight at Kitty Hawk, North Carolina in 1903. While most flight simulators are intended to permit the practice of flying skills without risk to the safety of the operator, some of the first possessed a low level of fidelity overall. Like the criticisms made against early medical simulators for teaching skills of midwives, some individuals contended that little would be learned from flight simulators that could be transferred to an actual aircraft. For example, Haward (1910) states,

> there is a tendency to design such an apparatus [a flight simulator] merely for purposes of balance and without any real resemblance to an actual æroplane, while the very balance is so exaggerated that the pupil is placed under conditions that are in no way so arduous as free flight. (p. 1006)

No description of these crude simulators is provided, however.

Sanders Teacher

To overcome both the demonstrated and perceived limitations of pioneer aircraft simulators, a new device was invented based on a Sanders biplane and made by that company. Called the *Sanders Teacher,* this simulator consisted of an aircraft fuselage mounted on a base that could pivot, rock from side to side and could revolve about a vertical axis. At rest, the fuselage is supported in a level attitude, but with either the nose or tail resting on the ground. While the fuselage supports elevators and rudders similar to the Sanders biplane, the Sanders Teacher was equipped with a single small spar on each side of the fuselage rather than two wings. Each of these spars supports a small aileron. The spars and ailerons function in a similar manner to the wings of the biplane. Figure 92 (after drawings in Haward, 1910, p. 1006) shows the side and overhead views of a Sanders Teacher as well as a detailed view of the turntable used to support the fuselage.

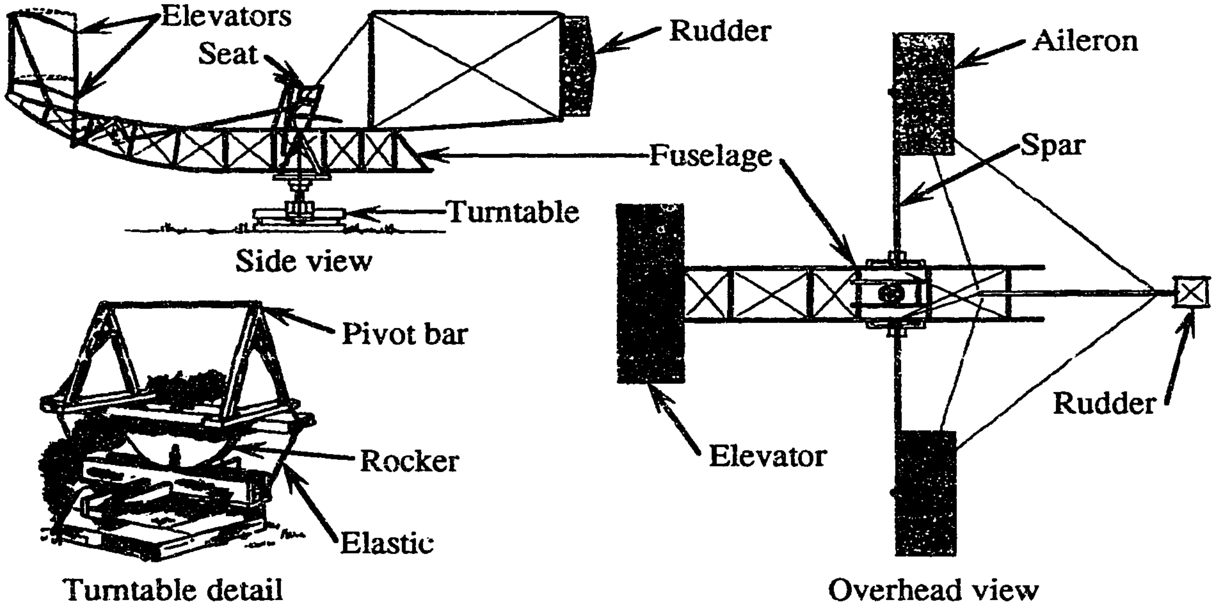


Figure 92. Views of the Sanders Teacher flight simulator

It is necessary to place the Sanders Teacher out of doors in a windy location. The wind not only enables the fuselage to be levelled, but it permits the simulator to be manœuvred like a flying aircraft. In a manner similar to an aircraft, the movement of the wind over the surface of the ailerons and elevators tends to lift the Sanders Teacher. The simulator was equipped with small wing surfaces likely to limit lift, preventing the wind from lifting the simulator off the ground. Once seated in the simulator, the operator could move the control wheel and pedals in the manner of a flying aircraft, causing the ailerons, elevators and rudder to be repositioned. Through a system of elastic ropes, a rocker and rollers, the base permits the fuselage to bank, turn, dip and climb (Haward, 1910).

Using the simulator, the prospective flyer can gain experience practicing accepted manœuvres and may also experiment with different manœuvres. An experimental manœuvre that would cause a flying aircraft to stall or crash, causes the Sanders Teacher to touch the ground. In this way, the simulator provides instructive feedback without placing either the operator or the apparatus in danger. The design of the base prevents high, since Haward (1910) reports that most of the parts can be used to assemble a flyable aircraft. The economy of this feature is also cited as an incentive for using the simulator. The effects of particular environmental conditions, such as the icing of the wings, cannot be simulated with the Sanders Teacher. Use of the simulator is also dependent upon the ambient wind. If there is no wind, or its velocity is too low, then there will be insufficient lift to permit the Sanders Teacher to be manœuvred. In spite of these limitations, it is contended by Haward (1910) that skills learned on the Sanders Teacher can be transferred successfully to a flying aircraft. It is assumed implicitly, that once basic flying skills are mastered on the simulator and transferred to actual flying, the attention of the flyer can be directed to the learning of additional flying skills not teachable by the Sanders Teacher. A photograph in Parrish (1969, p. 55) indicates that similar simulators were being constructed by others at about the same time. It is not known how many Sanders Teachers or similar early flight simulators were constructed.

The limitations of fixed simulators such as the Sanders Teacher were of concern to other individuals who maintained that greater fidelity in simulation was necessary to ensure appropriate transfer of learning. Ringham and Cutler (1954) describe other simulator designs contemporary with the Sanders Teacher. While these simulators also used actual fuselages, most of these simulators were not fixed to the ground. Some were supported by balloons, while others were positioned on gantries and wheels, and were pulled along to provide sufficient air movement (Ringham & Cutler, 1954). This design not only simulated some of the movement encountered in flight, but it also ensured that the simulator could be used when sufficient ambient wind was lacking. Ringham and Cutler (1954) mention British, French and German patents dating from 1917 through the late 1920s, that describe designs for different flight simulators. While it is not known whether any of them were constructed, some features described anticipated later developments such as computer-controlled simulations.

Penguin system

While flight simulators were being developed and used before the First World War, none seem to have been used to train pilots by any air force in that conflict. It seems that learning and practicing with actual aircraft was the preferred method of instruction in the First World War. It is important to note that not all flight training and practice took place in the air. Kelly and Parke (1970) describe a training method developed by the French during the First World War, referred to as the *Penguin system.* With this method, a prospective flyer was allowed to manœuvre an actual powered aircraft, but only on the ground, hence the name in reference to the flightless quality of the penguin. Using the Penguin system, the trainee would learn the functions of the various controls while also gaining familiarity with the sounds and motion of the aircraft. By not leaving the ground, neither the aircraft or the pilot were likely to be damaged severely. Kelly and Parke (1970) report that the Penguin system resulted in the trainee gaining sufficient skill with the aircraft and that the entire time required for training was reduced with no apparent compromise in flying skill. Knowledge of the Penguin method is attributed, in part, as contributing to the invention of a popular flight simulator by an American organ maker who was also an amateur flyer.

Link flight trainers

Although Edwin Link had learned to fly by 1927, his finances prevented him from purchasing a plane. He contended that his flying skills would not improve and would probably deteriorate without regular practice. While one may obtain some practice by taking flying lessons, apparently few owners of aircraft were willing to let them be used for prolonged periods of practice (Kelly & Parke, 1970). Recalling the Penguin method, inherent in actual aircraft. Using the facilities and materials in his father's organ and piano factory, Link constructed an operational prototype by 1929 (Kelly & Parke, 1970).

Although some later versions of the Link Trainer became more elaborate and complex, the versions constructed before the end of the Second World War all shared common operating principles. A small plywood fuselage complete with truncated wings and a cockpit appointed realistically, was mounted on a frame supported by a vertical shaft. A system of bellows connected the fuselage to the frame. By means of an electrically-driven turbine, a system of valves and distributing tubing, air can be selectively evacuated from the bellows, causing the fuselage to move. A vacuum-operated engine, connected by a belt to the shaft, could rotate or spin the entire fuselage. In most instances, movement of the fuselage is controlled by the operator moving the control stick, or wheel in particular models, and pedals. Figure 93 (after drawings in Link Trainer *handbook*, 1939) shows a portion of the vacuum control system and fuselage support frame of a Link Trainer.

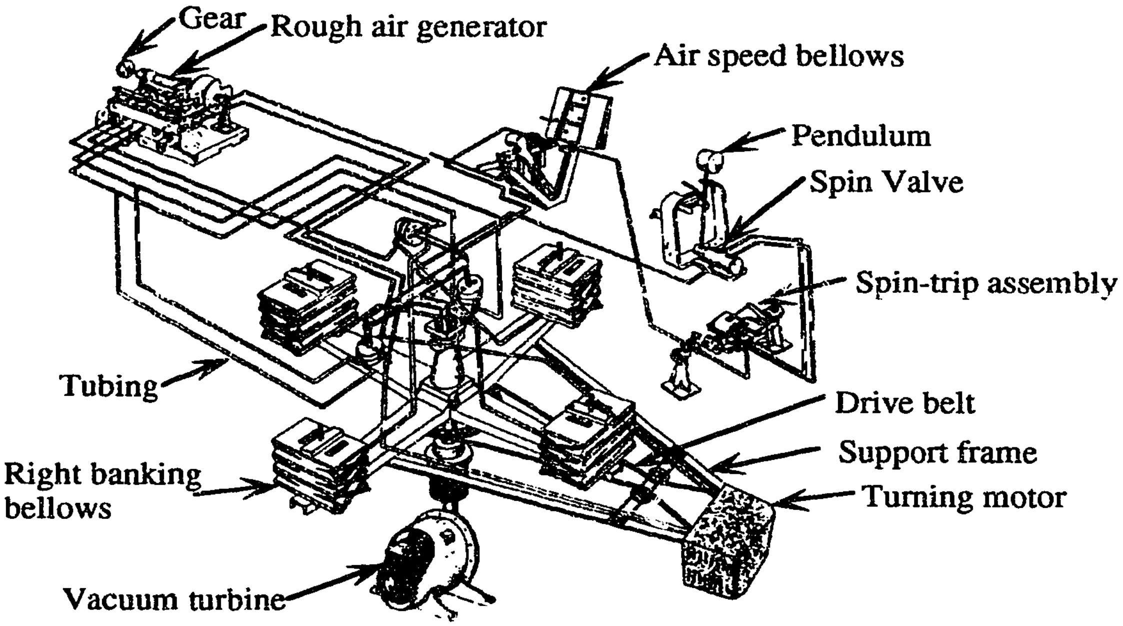


Figure 93. Support frame and vacuum system schematic of a Link Trainer

Changes made in the attitude, direction and simulated air speed of the simulator would alter any instruments in the cockpit correspondingly. A vacuum system rather than compressed air was selected because most of the instruments in the cockpit were actual instruments found in real aircraft, and these require vacuum rather than compressed air (*Link Trainer handbook*, 1942). In this manner, the Link Trainer simulates the motions of an actual aircraft. To be sure, the fidelity of flight as produced by the first versions of this simulator was less than that of an actual aircraft. Kelly and Parke (1970) note that the first model Link Trainers, "lurched and wheezed as the students manipulated the controls. It was not much like flying an airplane, but there was movement and it was generally consistent with what an airplane could be expected to do" (p. 7).

While Link envisaged his trainer as an instructional device, few concerns appeared interested in it initially. The first version of the trainer, designated *Model A*, were equipped with a coin-operated switch and were sold to amusement parks. Kelly and

Trainer in 1930 was $750.00 at the factory in Binghamton, New York. A counter with numbered dial from zero to fifteen, and a pointer that could be advanced incrementally was also supplied with these units (Canadian Department of National Defense file 74/19 Vol. 1). The pointer was advanced each time the trainer deviated from a level attitude. The object of the game was to keep the counter to as low a number as possible. As an incentive, some amusement parks offered prizes for low numbers (Kelly & Parke, 1970). With this apparatus, an individual could learn some of the manœuvres required to keep an aircraft level in flight. While most units were sold for amusement purposes, Link retained some and started his own flying school, where students received an initial portion of their training on the simulators. Although Kelly and Parke (1970) report that the school was successful initially, it succumbed to the effects of the Great Depression in 1930.

During this time, advertisements and reviews of the Link Trainer in periodicals brought the device to the attention of American and foreign military organizations as well as flying schools. The United States Navy purchased a single unit to teach flying by instruments. In this configuration, the cockpit of the simulator was enclosed with a hinged hood, forcing the student to rely on instruments rather than outside visual cues. Kelly and Parke (1970) report that the Navy was impressed by the efficacy of the trainer, since Link was able to teach an officer who had never been in a plane to fly by instruments. After training with the simulator, the officer was able to transfer his knowledge and skill to an actual aircraft. While the Link Trainer could save time and money by reducing the extent of training required with actual aircraft, the Navy considered the savings to be less than the cost of purchasing simulators, so no further orders were placed at that time (Kelly & Parke, 1970).

The British Royal Air Force (RAF) and the Royal Canadian Air Force (RCAF) became aware of the Link Trainer in 1930 from a description of it in a periodical (Canadian Department of National Defense file 74/19 Vol. 1). Wing Commander L. J. Fiennes of the RAF investigated and tried out a Link Trainer personally. Fiennes' impression of it was discouraging. In a letter to the Director of the RCAF, Fiennes states, "I cannot believe that the device would be of any value for flying training... There has been a big demand for Link Trainers for use in Amusement Parks — a sphere to which I consider they properly belong" (Canadian Department of National Defense file 74/19 Vol. 1, p. 2). No elaboration is provided as to why the trainer was considered unsuitable, but it is apparent from the criticism that the appearance and popular deployment of the device rather than its demonstrated efficacy and underlying learning theory were the factors considered. The evaluation precluded the use of the Link Trainer in both air forces for several years.

While the British and Canadian air forces chose to use more traditional methods of instruction, the U.S. Army Air Corps, the forerunner of the United States Air Force, decided to purchase several Link Trainers because of a perceived need. Kelly and Parke (1970) report that in 1934, the United States Post Office cancelled all its private contracts for air mail carriage and instead requested the service be provided by the U.S. Army Air Corps. Most of the pilots did not have extensive experience flying by instruments, and several planes were lost and pilots killed at the outset of the service. Some administrators in the Air Corps realized that rapid training in flying by instruments was required if personnel and equipment losses were to be reduced. Finding no other instructional alternative, the Air Corps eventually purchased six Link Trainers at a cost of $3,400 each (Kelly & Parke, 1970). Ten trainers were also sold to the Imperial Japanese Navy in 1934. Later, four units were sold to the Soviet Union and some were also sold to the German *Luftwaffe* (Kelly & Parke, 1970). Well before the Second World War, Link Trainers were being used for training in two air forces that would later become enemies of the Allies. At the same time, the RAF and RCAF continued to ignore the demonto several commercial airlines in the United States.

Canadian interest in the Link Trainer did not return until 1936, when the trainer was reëvaluated as an instructional device, since interest was shown in it by Trans-Canada Airlines (Canadian Department of National Defense file 74/19 Vol. 1). At this time, the Link Company was considering opening a Canadian manufacturing and assembly plant, something it might not do if there were no orders. On this occasion, an RCAF Flight Lieutenant evaluated a recent version of the trainer and concluded, "I am satisfied that the correct use of the Trainer [version for instrument flying] would save at least ten hours flying time on the usual twenty hour instrument flying course" (Canadian Department of National Defense file 74/19 Vol. 1, p. 3). Considerable modifications and improvements had been made to the Link Trainer since its inception, and its cost in 1937 was $9,477.00 (Canadian Department of National Defense file 74/19 Vol. 1).

While the new versions of the Link Trainer continued to function in a manner similar to the original prototype, simulation fidelity was increased by the addition of several mechanical devices and interactive features. While functional instruments had been developed for the initial model, it was usually difficult for an instructor to monitor the performance of the student closely. Some feedback to the instructor was required to facilitate his/her effectiveness. The apparatus was also incapable of simulating particular flying conditions that could require special procedures. The design of the simulator with the hinged cockpit hood could also provide severe discomfort to individuals trying to learn flying by instruments, since there was no ventilation system in the first versions. Besides making the students uncomfortable, excessive heat could also distract their attention from the primary purpose, the instruments. Revisions to the Link Trainer were devised to address these problems and limitations.

New versions of the Link Trainer were equipped with a special instructor's table. This table held simulations of the instruments located in the cockpit of the Link Trainer. To simplify operation and maintenance, electrically-operated instruments were used at the instructor's table instead of ones that were vacuum-operated. The readings on the instructor's instruments were controlled by teletorque motors. These synchronous electrical devices operate in pairs according to a *master-slave* principle. One of the motors, the *master*, is located inside the simulator and its shaft is rotated either by movement of the simulator or by a transducer that transforms changes in vacuum into physical motion. Moving the shaft of the master teletorque motor induces a voltage that causes a corresponding change in position of the shaft of the second or *slave* motor (Link Manufacturing Company, 1942). The instructor is able to see the same instrument readings as the student in the cockpit with this arrangement. By using two-way radio communication, either voice or morse code, the instructor is able to interact with the student and to provide corrective feedback and/or instructions.

Several mechanical devices were added to create simulations of particular flying conditions. One condition encountered commonly is turbulence or rough air. Simulation of this feature is accomplished by placing spring-loaded valves in the vacuum lines going to the bellows. Cams on a motor-driven cam shaft located next to the valves, press the individual valves at different times and for different durations. These actions cause the bellows to undulate and this action pitches the fuselage. The camshaft and valve arrangement is called the *rough air generator*, and it is visible in Figure 93, shown previously. This feature is activated or suppressed by the instructor (Link Manufacturing Company, 1939). To simulate the effects of slipstreams acting on an aircraft, which results in stiff operation of controls, *slipstream simulators* were devised and added to the new trainer.

A slipstream simulator consists of a metal cylinder containing an oil, in which a shaft possessing radial vanes is also contained. A valve inside the cylinder controls the passage of oil from one side of the vanes to the other. This arrangement imparts an adjustable resistance to turning the shaft. An adjustable nut at one end of the shaft controls the aileron control (Link Manufacturing Company, 1942). Both the rough air generator and the slipstream simulators must be adjusted before the simulation begins, since remote adjustment from the instructor's table is not possible. By adjusting the slipstream simulators and controlling the rough air generator, an instructor can cause the Link Trainer to simulate a variety of flying conditions that the student will have to contend with.

Some errors in flying cause the aircraft to enter a spin. Failure to perform the correct compensating manœuvres usually results in a crash. To cause the simulator to spin, two valve assemblies were installed. Both are visible in Figure 93. A stall is one manœuvre that will cause the simulator to enter a spin, like many actual aircraft. Since the simulator is not moving through the air, a pendulum valve is used to simulate the condition of a stall. When a student places the simulator in too steep a climb, usually resulting in a stall if an actual aircraft is being flown, the pendulum of the valve falls to one side, opening vacuum lines to the spin trip assembly which activates the turning motor. At the same time, the needle of the air speed indicator begins to fall rapidly. The fuselage then rotates rapidly while the altimeter needle falls. The spin stops only when the altimeter reaches zero, indicating a crash, or when the student performs the correct manœuvres to recover from a spin (Link Manufacturing Company, 1942).

The modifications made to the Link Trainer not only increased the fidelity of particular attributes, but they also facilitated interaction between the instructor and the student. By the time that the new versions of the Link Trainer became available for sale, it was apparent to the Link Manufacturing Company, as well as to training personnel in the air forces of Canada, the United States and the United Kingdom, that the effectiveness of the Link Trainer was in large part dependent upon the skill of the supervising instructor. After the RCAF's re-investigation of the Link Trainer in 1936, for example, a Flight Lieutenant reported, "It is obvious that the instructor should be well trained to get the best results from the equipment" (Canadian Department of National Defense file 74/19 Vol. 1, p. 8). The Link Manufacturing Company offered a course of three months duration for owners of Link Trainers and the company also offered special courses to military personnel who were to be Link Trainer instructors (Canadian Department of National Defense file 74/19 Vol. 1). The importance of proper instructor training was increased by a further modification of the Link Trainer.

While an instructor could see the same instrument readings as the student and could provide immediate feedback and guidance, there was no provision for recording the manœuvres of the simulator, so that the student might observe what he/she had done during the simulation. A specialized recording device was invented and equipped with a new model Link Trainer, designated *Model D*, beginning in 1937 (Canadian Department of National Defense file 74/19 Vol. 1). A teletorque motor connected to the main shaft of the simulator through a system of gears, controlled a slave motor housed in a vertical orientation between upper and lower members of a triangular metal frame, oriented horizontally, also containing a system of gears and a second motor controlled independently. The two-piece triangular metal frame is supported on three cylindrical shafts with small rollers at their base. The independent motor is connected to drive the rollers of two adjacent shafts at one of two constant speeds, while the teletorque motor turns all three shafts by means of the system of gears. The roller not driven by the independent motor touches a felt roller saturated with ink, suspended above. This assembly, referred to as the *automatic recorder* or *flight log*, was designed to be placed on top of a map or chart located on the instructor's table (Link Manufacturing Company, 1942). When the simulator is in operation, the automatic recorder or *crab* as it is referred to commonly, travels across the map or chart (Kelly & Parke, 1970; Parrish, 1969). This action leaves a visible trail, since the roller touching the inked felt roller leaves a path of ink on the map. The direction of the recorder is controlled by the actions of the student in the simulator, since *structions* (1942) states, "The low speed is used for instrument and radio orientation problems and the high speed for instrument landing problems" (p. 70). Figure 94 (Provincial Archives of Alberta, Alfred Blyth Collection, Bl. 520) shows two Link Trainers as installed at the Empire Air Training school in Edmonton, Alberta, sometime during the Second World War. The automatic recorder and the instruments should be noted on the instructors' tables as well as the hoods on the trainers themselves.

Figure 94. (Provincial Archives of Alberta, Bl. 520) A Link Trainer installation

The purpose of the simulators shown in Figure 94 is to teach the principles and psychomotor skills required for flying by instruments. After the student demonstrates a level of mastery satisfying the instructor, then the student practices and demonstrates his/her skills on an actual aircraft. If the student is able to perform the learned skills on the actual aircraft, it may be contended that the transfer of learning was successful. Successful transfer of learning was of concern to some military Link Trainer instructors. Kelly and Parke (1970) report that although students who learned flying by instruments on the Link Trainer did transfer the skills to actual aircraft, dissimilarities between the simulator and the aircraft sometimes interfered with this transfer. To improve transfer of learning, Link designed a new version of the Link Trainer with a cockpit layout identical to the training plane used after learning on the simulator. Fidelity overall was improved by the addition of fuel tank indicators, while attribute fidelity was improved by electronic circuitry that could introduce static and interference into the radio system. Kelly and Parke (1970) state that this version of the Link Trainer not only improved the transfer of learning, but that it possessed a high level of fidelity that fooled even some experienced flyers. The improvements to the Link Trainer, coupled with the perceived need for them by the

While most of the initial models of the Link Trainer were designed to teach the principles of flying by instruments, other flight simulators were manufactured during the Second World War for other purposes. Roberts (1943) reports that one problem faced by the RCAF was how to determine which recruits were suitable to become pilots. Although intelligence and aptitude tests were used for initial screening, these measurement instruments do not reveal any psychological phobias or physiological conditions that might prove undesirable for pilots. To save both time and the cost of training, a version of the Link Trainer was developed as a testing instrument. While the basic design was similar to other Link Trainers, the fuselage was equipped with two wings to more closely resemble the biplane trainers used at the time. No hinged hood was provided, as the student was supposed to look about while in the simulator. The apparatus was surrounded by a large cylinder. The inside of the cylinder, facing the simulator, was painted with ærial views of the ground and clouds. Aspiring pilots were directed to the simulator and told to try flying. As the simulator rotated, pitched and spun, it was found that individuals suffering from vertigo or motion sickness would soon become nauseous (Roberts, 1943). Nausea would disqualify the individual immediately from further training, since nausea distracts the flyer and it can be fatal when a breather mask is worn. Kelly and Parke (1970) report that before Link Trainers were developed for this purpose, recruits were usually taken up in a training aircraft flown by an experienced pilot who would perform rolls and other manœuvres likely to induce nausea in the recruit. The test version of the Link Trainer accomplished the same goal as the training aircraft, but without expense of fuel and the time of an experienced pilot. In this application, the Link Trainer continued to be an instructional device, since both the student and the instructors learned whether the individual in the simulator was capable of further pilot training.

Other models and versions of the Link Trainer were designed to teach special skills and procedures without posing undue risk to the students, or requiring the use of scarce aviation fuel. Parrish (1969) and Kelly and Parke (1970) describe a Celestial Navigation Trainer intended to improve the accuracy of night bombers. Housed in a special building, this trainer consisted of a dome-shaped metal screen suspended from the ceiling by a moveable support. The screen holds small lights to simulate the positions of 379 stars (Kelly & Parke, 1970). The building also contained a fuselage designed to hold a regular bomber crew. The fuselage was supported on a track running vertically along one wall. A moveable floor was located below the fuselage (Parrish, 1969). Special projectors located along the walls of the simulator building could project images of terrain on the floor and walls to permit navigators to navigate using particular land marks. The Celestial Navigation Trainer was used to instruct several skills. Besides teaching how to navigate by using stars, the trainer was also designed to teach bombardiers to use bombsights accurately, and to teach the individuals of the crew to work together as a team (Kelly & Parke, 1970).

The Celestial Navigation Trainer was equipped with a special feature controlled by the instructor, a feature not seen in simulators since Smellie's devices. Kelly and Parke (1970) state, "If ragged or sloppy crew habits developed, the instructor would be quick to detect this and, by means of his 'freeze' button, could stop the action at any point and review the correct procedure" (p. 67). Like Smellie before and Skinner later, the designers of the Celestial Navigation Trainer contended that immediate corrective feedback following a particular action is essential to ensure that the intended procedure is learned. The Celestial Navigation Trainer appears to have been effective as an instructional simulation, since Kelly and Parke (1970) state that the RAF reported a 50% decrease in training time required for bomber crews who used the simulator. Some Link Trainer versions were designed to simulate damaged aircraft, thus providing pilots with skills and

(1970) claim that the RCAF's Chief of Staff during the Second World War, Robert Leckie, stated, "the Luftwaffe met its Waterloo on all the training fields of the free world where there was a battery of Link Trainers" (p. 68). While this statement may not be entirely accurate, since both the Japanese and Germans had purchased early versions of the Link Trainer, it seems that the fidelity and the pedagogical application of flight trainers was developed more by the Americans, British and Canadians, than by the Germans and Japanese. Perhaps more than any other contemporary circumstance, the use of flight simulators during the Second World War shows how particular instructional devices can be used to address a perceived instructional need effectively. While flight simulations comprised only a portion of air force flight training, their apparent efficacy as instructional devices prompted other areas of military training to employ simulators. Some of these simulators will be described and discussed in subsequent sections.

Stationary flight simulators

The success of the Link Trainer as an instructional simulator during the Second World War prompted other companies to develop competitive versions. Ringham and Cutler (1954) state that in the United Kingdom, the Redifon Company devised a flight trainer during the Second World War that was made available commercially after the cessation of hostilities. In the United States, the Curtiss-Wright Aircraft Company also developed a flight simulator, designated as *type 400*, that was unveiled in 1945 (Ringham & Cutler, 1954). Unlike the Link Trainers that use pneumatics for much of the control and indicator circuitry, the Curtiss-Wright simulators use electrical components exclusively. In an apparent co-incidental development, both Link and Curtiss-Wright designed their flight simulators to reflect a different instructional theory than had been followed previously.

Kelly (in Kelly & Parke, 1970) reports that when he joined the Link Company at the end of the Second World War, he introduced a new design concept based on studies conducted by the Standardization Board of the United States Air Force. It was noted by some military personnel, especially experienced flyers, that the motion of the Link Trainers was not identical to that of actual aircraft, because the centre of gravity of simulators was usually higher than that of most aircraft. It was contended, therefore, that the sensations experienced by students using a moving trainer would be different than those of actual aircraft (Simpkins & Emms, 1953). Kelly (in Kelly & Parke, 1970) states, "I had become convinced that the motion was being provided was incompatible with the feel of a real airplane and therefore should be done away with" (p. 70). At the same time, an employee of the Curtiss-Wright Corporation, Dr. Richard Dehmel, also concluded that the motion inherent in the wartime Link Trainers possessed too low a degree of fidelity to effect transfer of learning from the simulator to the aircraft (Kelly & Parke, 1970). Moreover, Dehmel also contends that motion in flight simulators is superfluous and distracting, since it seems logical that when flying by instruments, the student should not use physical sensations as cues for position or direction (Kelly & Parke, 1970). Both Link and Curtiss-Wright decided that while interaction between the machine and the student should be preserved, the simulation should be less dynamic than before. Although the ostensible reason for moving towards stationary simulators was pedagogical efficacy, an employee of the Link Company is reported as stating that the cost of introducing motion into simulators of complex aircraft would increase the cost of simulators considerably (Klass, 1952a). This factor is important, since a selling point of simulators is that using them for training is less expensive than using the actual aircraft (Christian, 1951).

The configuration of most stationary flight simulators is similar. A portion of an actual aircraft, or a simulation of it, is used as the part of the simulator occupied by the student or students. Placed nearby is an instructor's control panel, communications station, and equipment cabinets required for the operation of the simulator. Curtiss-

Wright began marketing one of the first electronic stationary flight simulator in 1948 (Christian, 1951). Ringham and Cutler (1954) report that the simulator of a Boeing 377 Stratocruiser reproduced, "all the aerodynamic, engine and handling performance and furnishings in facsimile" (p. 154). The simulation and control of all these aspects, plus providing simultaneous feedback, was beyond the ability of simple electro-mechanical circuits. Instead, a number of analogue computers were used to control specific parts of the simulator and to provide feedback (Klass, 1952b). The simulator controls are connected either to switches or non-linear potentiometers which transduce physical position into specific voltages. Using Alternating Current (AC) in the initial models, Direct Current (DC) in later models, and operational amplifiers comprised of vacuum tubes, these analogue computers were able to compare physical settings and movements of the simulator's controls with acceptable values represented by particular voltages within the amplifier circuitry. On the basis of comparison, the computers cause indicators in the simulator and on the instructor's control panel to change. In some instances, if the actions on the simulator's controls are severe enough, the analogue computers will energize warning devices or mechanical systems that simulate particular events (Klass, 1952b). While motion of the entire simulator is lacking, attribute fidelity is maintained, usually to a high degree. Sound effects of engines and the results of particular maœuvres are provided either by playing back recordings, or by artificial means. Klass (1952b) reports that in some Curtiss-Wright simulators, engine sounds are produced by an opaque disk and photo-electric cell arrangement similar to the Cardionics heart sound simulator described in a previous section. The sound of aircraft wheels touching the runway are simulated by a capacitor discharge circuit. By controlling the volume of specific speakers, a simulation of sound direction can be created (Klass, 1952b). Most stationary flight simulators can also generate a loud, unpleasant noise to signify a crash. Situational feedback can entail simultaneous simulation of many elements. In some Link stationary simulators, for example, placing the simulator in a stall results in several instruments changing their indication. In addition, warning lights and buzzers are activated and the control column begins to shake (Klass, 1952a).

Although specific feedback sequences are controlled by analogue computers, the entire simulation is not computer-controlled. As with the older Link Trainers, the instructor commands the course and progress of the simulation. Besides being able to add malfunctions and adverse flying conditions, the instructor can stop a simulation at any point to correct faulty procedures and actions immediately (Kelly & Parke, 1970). Although analogue computers enable many systems and events to be simulated and controlled simultaneously, most of these early computers occupied considerable space and contained many short-lived components. These features added to the difficulty of operating such flight simulators and maintaining them. For example, a DC-6B simulator manufactured by Canadian Aviation Electronics (CAE) in Montréal, in the early 1950s, consists of a simulation of the cockpit and flight deck of a standard Douglas DC-6B aircraft. The control and feedback circuitry contains 230 analogue computers, 600 vacuum tubes, 700 relays, 200 motors, all requiring a power supply with a capacity of 18 kW. The mass of the simulator, not including a three-ton (3 t) air conditioner for cooling the tubes, is 38,000 pounds (38,608 t). Wood (1952) reports that the electronic control circuitry and analogue computers for some stationary simulators could be even larger, "often containing as many as 1,000 electron tubes and consuming as much as 35 kw of power" (p. 1124). It is clear that stationary flight simulators of this type were used primarily by large organizations that could afford their capital costs and upkeep.

The seemingly effective elimination of movement from flight simulators combined with a rise in popularity of behaviorism and atomistic approaches to instruction, led to the creation of simple simulators designed to instruct only specific aspects of much larger procedures and operations. Gagné (1954) claims that the way most moveable and stationary flight simulators are used results in testing performance rather than providing systematic practice, since the student's attention must be divided among so many stimuli,

> it cannot be said that these procedures are designed to provide the kind of practice that is typical of actual aerial flight, because a great many more happenings of a critical nature are crowded into a ground trainer mission than would occur in the air. Instead these procedures usually reflect a desire to 'see what the student can do'. (p. 97)

Apparently ignoring specific goals of different flight simulators, the experience level of the students, and the context of flying, Gagné (1954) contends that the design of instructional simulators should not be dependent upon fidelity overall, but upon what specific skills or tasks the device actually teaches. He argues that an instructional device that attempts to simulate all the skills required to fly a helicopter is a helicopter, and that piloting a helicopter requires the mastery of several discernible discrete skills. Gagné (1954) contends, therefore, that a more effective instructional approach is to use either one device or several devices that not only simulate specific skills, but which also provide *instructive* feedback, opportunity for repeated practice and patterns of reinforcement as elucidated by B. F. Skinner. Gagné's (1954) contention is reinforced by citing studies of others which conclude that training using simple simulations of discrete skills of the actual process facilitate learning more efficiently than complex simulations requiring the performance of several skills at once. The examples cited, however, involve simple processes compared with flying an aircraft.

It is important to note that Gagné's (1954) analysis of flying an aircraft and ascertaining the most appropriate method of instruction was approached from a theoretical basis rather than from the basis of experience. It should be recalled that Link designed his trainer on the basis of his personal or *phenomenological* experience of flying, combined with the study of practical methods of instruction such as the Penguin method. The design of the Link Trainer was in part based on a perceived problem, that it is dangerous to life and equipment to make mistakes in the air while learning, a problem also perceived years earlier by Haward (1910). The design of the Link Trainer, therefore, was a practical solution to a perceived problem. Gagné's (1954) method of *task analysis*, is not designed to be a solution to a particular problem, but is intended to be a general theoretical approach applicable to all subject areas. Instead of addressing a particular problem, Gagné's (1954) approach is a solution that anticipates problems.

Some manufacturers, likely influenced by Gagné's and other researchers' advocacy of *task analysis* and its consequent atomistic style of instruction, designed instructional simulators that could teach only one particular skill required for flying. For example, it was ascertained that one such skill is *fine control sensitivity*. Johnson (1961) defines this as, "the ability to make precise, highly controlled adjustments, as in pursuit learning" (p. 212). To learn the correct movements of a control stick, therefore, simulators were designed to provide practice in this one skill. One example consists of a control stick projecting from a housing that also supports a board containing two rows of individual lamps. One row contains red lamps, while the other consists of green lamps. At the beginning of the simulation, a single lamp in the red row and a single lamp in the green row are illuminated. The position of the illuminated lamp in the green row corresponds to the position of the control stick (Johnson, 1961). Through mechanical or electronic means, the position of the single illuminated lamp in the red row is altered. The student is expected to move the control stick laterally to match the position of the green lamp with that of the red lamp. Errors in stick movement result in immediate visual feedback, since the position of the green lamp relative to the red will indicate the direction and magnitude of the error. A separate simulator is used for teaching students the relationship between pedal position and aircraft direction (Johnson, 1961). It is likely that these skills are brought together when the student attempts to fly an actual aircraft.

While Gagné's approach of using atomistic instruction may result in the student learning all the discrete skills necessary to fly an aircraft, the skills are learned in a linear fashion, rather like the way instruction is presented by a teaching machine using a linear program (see Chapters I & VI). As well, the skills are learned without context, so transferring the skill to a different environment may entail additional learning (see Guthrie, 1942). Gagné (1954) does not explain how the student learns the proper ways to integrate proprioceptive cues from the flight environment with the discrete skills learned previously, so that the aircraft is flown in a safe and efficient manner. While simple skills such as cutting a length of material with a specialized machine may depend upon the proper execution of discrete skills in a linear fashion, flying an aircraft requires the execution of many skills, sometimes contiguously and sometimes simultaneously. Some flight conditions that occur and must be contended with by the flight crew cannot be simulated in simpler form. The nature of these extraordinary conditions also make them extremely dangerous to perform on an actual aircraft. For example, Kelly and Parke (1970) state, "Many of the emergencies such as failure of two or more engines, or an engine fire, could never be practiced in the airplane" (p. 127). While such emergency situations occur rarely, it is considered beneficial if flight crews possess experience in contending with them successfully. Other stochastic elements of flying, such as unforeseen weather conditions, or being under fire in the case of military aircraft, are other examples of extraordinary conditions that most flight crews should be able to contend with.

To be sure, random and more complex elements can be added to a simulation once the instructor is satisfied that the student possesses sufficient mastery of basic skills to be able to cope with the new stimuli. This approach differs from that advocated by Gagné (1954), since additions to stimuli in a flight simulator are made in a particular context. As in actual flying, the context also requires the student to contend with the new stimuli in addition to those already present. Although Gagné (1954) contends that an atomistic approach to instruction enhances the transfer of learning from simulator to actual aircraft, there is evidence to show that this is not the case, since this instructional design ignores the possible rôle of parallel processing of simultaneous cues of different types. The element of simulator fidelity overall is not easily dismissed on theoretical bases, therefore.

Kelly and Parke (1970) describe an incident with a stationary simulator of a new military aircraft that had a tendency to roll over onto its back and crash. Like the actual aircraft, the simulator also possessed a tendency to roll and crash. An American Air Force Major with considerable flying experience entered the simulator and made the manœuvres necessary for take off. Kelly and Parke (1970) report, "at fifty feet, he rolled on his back and crashed. The horn went off and a red light came on indicating he was dead" (p. 85). Although the instruments indicated that the roll was leading to a crash, there were no physical sensations to guide the actions of the Major. By the time he realized what message the instruments were conveying, there was insufficient time to do anything before the aircraft crashed. In an actual aircraft, physical sensations not only inform the pilot about the attitude of the aircraft, they can also serve as a feedback loop, where the pilot governs his/her adjustments to the controls in part on perceived changes in physical sensation. For this feedback process to be effective, it must also be governed by additional cues or corroborative information, such as that provided by instruments and/or external visual cues.

The previous example indicates that in some instances, appropriate action is dependent upon the recognition and analysis of several stimuli simultaneously. Without the stimuli and their context, it is difficult or impossible for a pilot to select an appropriate skill or sequence of skills to keep the aircraft flying, even though the pilot may possess a repertoire of these skills. This view is shared by Parrish (1969) who states that in many instances, the first events informing a pilot that an extraordinary situation is present are physical cues, "Examples range from the bump and shock of air turbulence to the abrupt heave and pitch sensations caused by sudden engine loss. In both cases, pilot remedial action is required and the first 'cue' is provided straight through the seat of his pants" (p. 56).

Incidents of the type mentioned previously combined with the views of many experienced flyers, that physical sensations are indispensable cues for flying, began to persuade both civilian and military flight instructors that flight simulators should contain a high dynamic level as well as high fidelity overall, and that these elements should be presented contiguously. Such views contributed to the re-introduction of motion system in flight simulators beginning in the mid 1950s, as well as the simulation of high-fidelity visual information external to the aircraft (Kelly & Parke, 1970).

Later developments of motion systems in flight simulators

It is noted in the previous section that following the Second World War, simulators became more complex, requiring the use of heavy control equipment. The extreme mass of most modern simulators precludes the use of vacuum-based motion systems as used on the small Link Trainers developed before the war. It was also noted in the previous section that the motion system of the Link Trainers did not produce sensations that were faithful to those experienced in actual aircraft. While the presence of motion increased the overall fidelity of the Link Trainers, the attribute fidelity was low, since the sensations perceived were not congruent with reality. New methods of creating motion in simulators were devised to increase attribute fidelity.

At first, it was thought that the simulation of motion could be achieved without moving the entire simulator. Physical cues such as bumps and vibrations were simulated mechanically in some stationary simulators (Kelly & Parke, 1970). To simulate the gravitational force, or *g-force* of a turn, the seats cushions of some simulators change position and tension is created on the belts retaining the individuals. (Blatt & Gum, 1986). While devices of this sort can simulate the onset of gravitational forces, they cannot simulate prolonged g-forces. Blatt and Gum (1986) also notes studies which find that the use of so-called g-seats does not yield a satisfactory transfer of learning, since the sensations experienced are localized and do not affect some internal motion-sensing receptors such as those found in the middle ear. The authors share the view that successful training can be accomplished only by simulators possessing a high level of fidelity overall. For motion fidelity, Blatt and Gum (1986) contend that to provide the highest fidelity of motion, simulators capable of motion in *six degrees of freedom.*

Kelly and Parke (1970) state that the six degrees of freedom in simulator motion consist of longitudinal, lateral and vertical motion as well as yaw, pitch and roll. Most simulators capable of such motion employ an extensive hydraulic system, where the entire simulator is supported on an array of hydraulic cylinders. The deployment of such elaborate motion systems in flight simulators was dependent in part on the development of suitable digital computers (Huff & Nagel, 1975). While the first stationary flight simulators used analogue computers for attribute control and feedback, such devices are large, slow and inherently inaccurate. As resistors in the logic circuits become warm through use, for example, their resistance increases, thus diminishing the voltage in the circuits they control. Any change in voltage means that the accuracy of calculation is affected. To provide more accurate calculations and control of increasingly complex simulator systems such as motion and visual cues, the use of analogue computers was discontinued as soon as digital computers became available commercially by the 1960s (Kelly & Parke, 1970; Huff & Nagel, 1975). Using digital computers, flight simulators with elaborate hydraulic motion systems can be made to perform rapid sequential movements to simulate the six types of motion.

Some designers select different motion systems. One example is a helicopter simulator developed in Edmonton, Alberta, in the late 1950s. The apparatus, called the *Jaycopter*, was invented by Peter Jacobs, an aircraft engineer. A level of fidelity overall was achieved by simulating most of an actual helicopter and suspending it so that it could move like an actual helicopter. Instead of using hydraulic cylinders, the fuselage is secured by its bottom to a long, hinged boom by means of a pivoting support. The other end of the boom holds a counterweight assembly and an electric motor. The motor rotates a small propeller used for directional control. Electric motors also provide the motive power for the rotors of the helicopter. The main rotor is smaller than those found on actual helicopters, since less lift is required in the simulator. All of this apparatus is supported a distance from the ground by a steel tower. Figure 95 (Provincial Archives of Alberta, A. 8614) shows the appearance of a Jaycopter helicopter simulator being demonstrated at the Edmonton Municipal Airport in 1958.

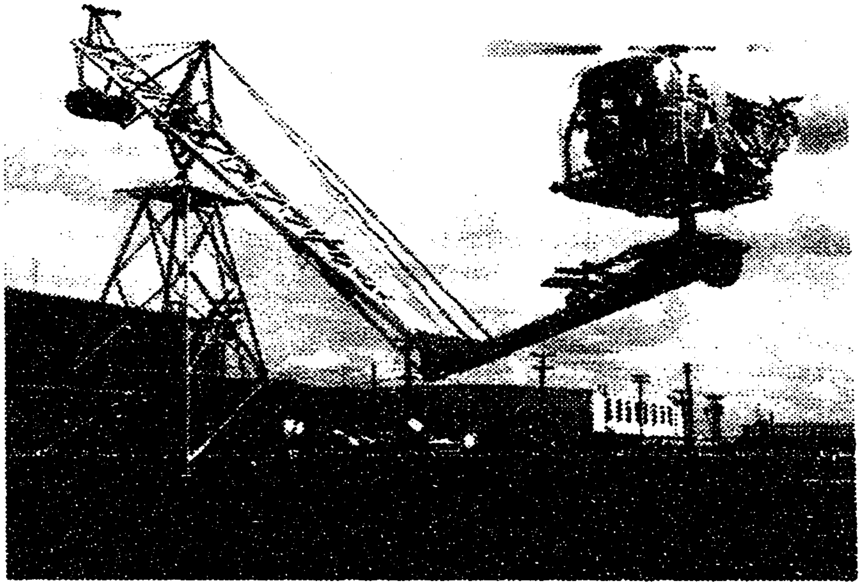


Figure 95. (Provincial Archives of Alberta, A. 8614) Jaycopter helicopter simulator

This type of simulator attempts to provide a higher degree of fidelity overall than other moveable simulators. Besides being located out of doors, thus providing a high degree of visual fidelity, the Jaycopter permits several motions capable of actual helicopters. While linear motion is restricted and modified, the Jaycopter facilitates flying experience without placing either personnel or equipment at undue risk. Unlike most other flight simulators, the Jaycopter is designed to hold the instructor as well as the student. With this arrangement, the instructor is able to provide immediate feedback to the student and may also provide demonstrations of particular manœuvres. The Jaycopter does not appear to have become a popular instructional simulation. Like the first Link Trainers, the Jaycopter was modified and marketed for amusement purposes. Modifications included a larger and less realistic fuselage without a tail rotor, a rigid boom and lift assist using hydraulic cylinders. These modifications suggest that the simulator was not capable of as many movements as its predecessor. Figure 96 (Provincial Archives of Alberta, D. 473) shows a later Jaycopter simulator being used for public rides at the Edmonton Municipal Airport in 1960.

Smaller, unmanned versions of the Jaycopter were manufactured as a coin-operated game. The model helicopter and support assembly are housed inside a clear acrylic sphere. The object of the simulation game is for the user, by manipulating speed and attitude controls, to move the model helicopter onto three landing targets in succession without hitting model trees. This procedure must be done within a limited time. If the simulator or its supporting boom hits a tree, then a switch is closed which resets the indicator lights and forces the user to begin again. While the small, game versions of the

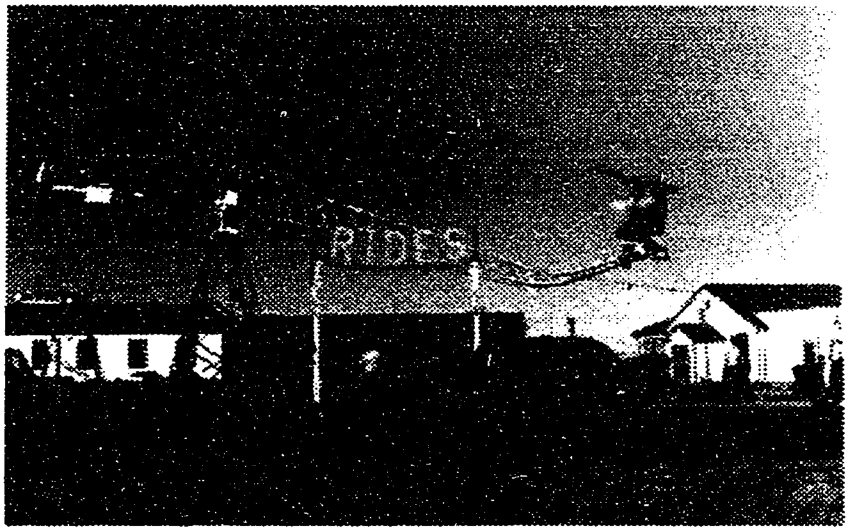


Figure 96. (Provincial Archives of Alberta, D. 473) Jaycopter simulator for amusement

Jaycopter are still to be found in the Edmonton International and the Edmonton Municipal Airports, the full-scale versions do not appear to be in use.

The market for such simulators does not appear to have been sustained, since the company abandoned production by the early 1970s. In spite of the development of other motion systems, computer-controlled hydraulic cylinders seem to be the most common form of motion system used for civilian flight simulators at present (Bray, 1986; Blatt & Gum, 1986).

While many flight simulators designed for the military also use hydraulically-based motion systems, Blatt and Gum (1986) note that particular phenomena such as sustained g-forces cannot be simulated with such apparatus. Some military aircraft must travel at speeds exceeding the speed of sound while performing rapid manœuvres. Such actions may create extreme g-forces on the pilot, adding another stimulus to be contended with. To simulate such conditions, some military flight simulators, including those that already possess hydraulic motion systems, are mounted on long fixed booms that can be pivoted horizontally. Unlike the Jaycopter simulators, the military devices are intended to spin the simulator suspended from the boom to create g-forces through centrifugal force (Blatt & Gum, 1986).

While the discussion of motion fidelity in the section concerned with stationary flight simulators might seem to indicate that the use and design of stationary simulators has been discontinued, the debate about the validity of high-fidelity motion in flight simulators continues. Huff and Nagel (1975) summarize several studies that endeavor to ascertain whether flight simulator motion facilitates or hinders the transfer of learning to actual aircraft. While the authors note that there is no apparent consensus, they note that many studies contend that too high a level of motion fidelity may affect learning adversely, a view also expressed by Fox (1960) and by Alessi (1988). On the other hand, Huff and Nagel (1975) claim that, "If the motion system [of a flight simulator] is of very low fidelity, pilot vertigo, nausea, or other noxious behavioral manifestations can result" (p. 434).

Considering these findings, Alessi (1988) proposes a three-level curve to model the appropriateness of motion fidelity to the degree to which transfer of learning is facilitated. While intended to show general trends, none of the curves appear to be drawn following specific data. Each curve represents an experience level of the student, novice, experienced and expert. In all three cases, too little motion fidelity results in poor transfer of learning. Alessi (1988) also contends that novice students are more likely to be distracted by stimuli not immediately related to the task being learned, so a high level of motion fidelity may hinder learning rather than enhancing it, hence the drop in the level of transfer for the *novice* as the curve approaches high-fidelity. Expert learners, however, are thought to rely upon numerous cues, so a simulator with high motion fidelity is likely to facilitate the transfer of learning. This analysis addresses the problem of motion fidelity by classifying students into distinct experience groups and then matching them to simulators with an appropriate degree of motion fidelity. After students learn all they can at one level, they then proceed to the next level. The final step is to leave the simulator and perform the learned skills in an actual aircraft. Alessi (1988) likens this process to Bruner's (1966) concept of the *spiral curriculum*. While this approach seems to solve the problem of what level of motion fidelity should be present in flight simulators, the method creates and intensifies several problems that are not easy to address and solve. Alessi (1988) notes several problems in trying to apply this approach, such as what constitutes high and low fidelity and how one can ascertain when the student is at the level where the fidelity of motion is too low to facilitate a transfer of learning. Besides these problems are more generalized considerations, such as whether a high level of motion fidelity is actually high, or is just perceived to be high because of the limits of technology or the underlying instructional theories ascribed to by the designers of the simulator.

An example of how this consideration is important in simulator design are the findings of the analysis of the recent crashes of the Canadian military CF-18 aircraft. Between April 1984 and April 1990, eleven CF-18 aircraft crashed while on routine patrol or training exercises (Hunter, 1990). After mechanical errors had been eliminated, investigators concluded that some condition was causing the pilots, who were all experienced fliers, to make serious errors. One conclusion was that the flight simulators used for the CF-18s did not provide sufficient motion fidelity. In a press report ("Dizziness probed", 1990) Canada's senior Flight Surgeon, Lieutenant-Colonel J. Popplow, allegedly states that the simulators used for the CF-18s only provide centrifugal force, while those used for the Amercian F-18 aircraft also include other motion systems that operate simultaneously with the centrifugal force. It is contended further that this limitation of the CF-18 simulators leads to pilot disorientation and dizziness when the actual aircraft is flown, since the pilot does not possess prior experience contending with the combination of physical forces present in the actual CF-18. The foregoing discussion illustrates the difficulties in ascertaining the actual level of attribute and overall fidelity of simulators. The discussion also shows how the questions of fidelity and transfer of learning are not contended with or resolved easily.

Later developments of stationary flight simulators

Some recent flight simulators avoid the problem of motion simulation altogether by being stationary. The absence of motion in such simulators is not an acceptance of the view that motion is a distraction to the learning process. Instead, most of these recent stationary simulators are designed to address instructional goals different from the flight simulators discussed to this point. While most flight simulators are intended to teach particular psychomotor skills necessary for flying, the instructional goals of recent stationary flight simulators are either to increase the pilot's knowledge of skills incidental to flying, or to provide information to researchers (Wickens, Haskel & Harte, 1989). In consequence, such simulators usually possess high fidelity of cockpit layout or configuration.

Some of the first examples of newer stationary simulators were those developed by Link in the mid 1960s, for the American Apollo space program. It was considered necessary by the National Aeronautics and Space Administration (NASA) for astronauts to practice procedures and manœuvres with the required equipment before actually travelling to the moon and attempting a landing on its surface (Kelly & Parke, 1970). The inability of the original equipment to provide feedback is likely the main reason why simulators were deemed necessary for training. Several problems precluded motion systems being installed in the simulators. Some motions such as the interaction of the Lunar Excursion Module with the moon's gravity (especially the surface characteristics) could not be simulated in part because there was no empirical knowledge of the phenomenon at that time. As well, simulating the supposed effects of the moon's gravity and simulating weightlessness are beyond the capabilities of current motion systems. Although weightlessness can be reproduced on the earth in aircraft flying in a particular parabolic arc, the effect lasts briefly, so a sustained simulation is not possible. Brief periods of weightlessness lack the fidelity of space, so it may be contended that the repeated presence and absence of weightlessness, caused by the travel of the aircraft, disrupts learning rather than enhancing it. Since the astronauts already possessed experience with space travel, the main concern was for them to learn correct procedures (Kelly & Parke, 1970). Given this instructional goal, stationary simulators are satisfactory. Two different simulators were designed, and several examples of each were supplied. Kelly and Parke (1970) report that one type simulated the Command Capsule and its journey from the earth to the moon and return, while the other was a full-scale simulation of the Lunar Excursion Module. While the internal appearance of the simulators resembled the actual equipment closely, the simulators were made of less expensive materials, since they were not destined to travel in space. In spite of the absence of motion, fidelity of other attributes was kept to a high level. Recordings provided sounds of machines and rockets firing, and some visual fidelity was provided by elaborate CRT-based visual systems using fixed and moving models. Each simulator was controlled by a custom-designed digital computer (Kelly & Parke, 1970). While the simulations run on these devices were intended to occur in real time, Kelly and Parke (1970) report that one part of one simulation, travelling in space between the earth and the moon, could be sped up to 30 times real time, "so astronauts may concentrate on critical phases of the mission without having to go through long periods of inactivity" (p. 159). Like some flight simulators, the simulations run on the lunar simulators could be interrupted and stopped at any point immediately, so that instructors could correct errors as they occurred.

Although space flight simulators represent one recent and specialized application of stationary simulators, some aircraft flight simulators are manufactured without motion systems. One company marketing stationary flight simulators is Virtual Prototypes, Incorporated. Most models are controlled by a number of digital computers, and most present information by means of CRT-based video displays (Virtual Prototypes, 1988a). These simulators are multi-purpose devices designed to be configured in many possible ays, "The resulting simulator can be used for R&D or training purposes. Several such simulators can be interconnected to explore team operation issues" (Virtual Prototypes, 1988b, p. 1). While being able to provide instruction to flyers, these stationary simulators may also be used to instruct researchers about the ergonomics of existing or experimental apparatus. These simulators may be used to evaluate the design of equipment for actual aircraft, and may also be used to design, study and modify simulator systems. A simulator that can be modified to present visual information in different ways, likely facilitates the development of improved visual systems. By not including motion in the simulation, it may be contended that at least one possible confounding variable is eliminated from the study of visual systems. Wickens, Haskell and Harte (1989) describe experiments using different perspective views for simulator visual systems. The purpose of their studies were to study the interaction between pilots and the different visual systems. Although motion exists in all flying aircraft, the sensation was considered a distraction in the studies, since the researchers were concerned primarily with the ways pilots interact with different visual systems, not with how pilots divide their attention among different environmental cues. By using simulators in these ways, designers may learn whether or not their abstract ideas, which are transformed into reality by the simulator, function or interact with users in the ways envisaged. Using simulators rather than actual aircraft for initial testing preserves the safety of personnel and equipment and enables most experiments to be carried out with less expense than using actual aircraft.

Some computer software companies such as Microsoft, market software-based flight simulators designed to be run on personal microcomputers. Unlike the apparatus marketed by Virtual Prototypes, software-based flight simulators possess low fidelity overall and low fidelity of most attributes. The control stick/wheel, for example, is simulated by a mouse, joystick or similar type of input device. Unlike an actual control stick/wheel, most common computer input peripherals cannot provide feedback or simulate particular input conditions such as the effect on the control stick/wheel of ice on the wings. While the user may learn some of the basic principles of flying from software-based flight simulators, the fidelity of the simulation is so low that it is doubtful that much transfer of flying skills would occur between the simulation and the flying of an actual aircraft. It is likely, therefore, that such software-based simulators are useful primarily for entertainment.

As noted previously in this section, an area where stationary simulators are used extensively is the development and testing of visual systems both for simulators and for actual aircraft. Like motion systems, there is considerable debate as to what level of fidelity should exist in visual systems to ensure a positive transfer of learning.

Later developments of visual systems in flight simulators

In spite of the complexity of the control circuitry, most early stationary flight simulators did not include images of the ground, sky or stars. Cockpit and flight deck windows, while being present, were frosted to give the impression of heavy fog (Simpkins & Emms, 1953). This was not considered a limitation, especially if the goal of the simulator was to teach flying by instruments to experienced pilots and flight crews. In such instances, external visual cues are contended to be superfluous. Problems arose when simulators were intended to instruct flying skills peculiar to specific aircraft. As noted in previous sections, it was found that without additional cues such as physical sensation and external visual information, errors in judgement and procedure could result in disastrous consequences. Painted representations of land and terrain were used previously in particular models of the Link Trainer, including the Celestial Navigation Trainer. This method of simulating environmental visual cues possesses a low level of fidelity and its use is limited, since it cannot be used with stationary simulators and proper alignment is a problem with moveable simulators. Other attempts at simulating external visual cues use either still or motion pictures and fixed-screen projections of a pilot's view of a runway. As the simulator moves, or as the controls are altered on stationary simulators, the position of the image relative to the cockpit windows also changes. This depiction of relative motion provides visual feedback to the pilot, facilitating the execution of proper corrective action. Although some visual feedback is provided with this type of simulation, Parrish (1969) reports that the images are limited primarily to take off and landing, and that the films cannot accommodate extensive deviations from the flight path.

One of the first successful attempts at creating a high-fidelity simulation of visual information outside an aircraft used a closed-circuit television system and a series of three-dimensional scale models of particular terrain and airport runways, a method sometimes referred to as the *fixed model approach* (Parrish, 1969). By means of a moveable support, the television camera may be moved across the model and be brought closer to particular areas. Control of camera movement is primarily by changes made to the cockpit controls by the pilot. The picture generated by the television camera is projected onto a lenticular screen in front of the cockpit windows of the simulator (Kelly & Parke, 1970). A system of mirrors arranged in a Schmidt configuration permit the projection of the television image from CRTs to the projection screen (Huff & Nagel, 1975). Kelly and Parke (1970) report that visibility deterioration caused by weather conditions can be simulated by varying the intensity of the projected image. Although televised images of scale models provided some degree of fidelity to external visual cues, early versions could only provide images in black and white. While the absence of colour may not appear to be an important attribute initially, it should be considered that many airports use lights of different colours to signify particular flight approaches, runway limits and ground travel lanes. The absence of colour, therefore, constitutes a loss of fidelity that could affect the transfer of learning adversely.

Although new versions of the fixed model approach are reported (Huff & Nagel, 1975) there are limitations inherent in the method. Parrish (1969) notes that the models used for the fixed model approach cannot be altered easily, so changes to the simulation are impractical. Most models are limited in size, and this limits the extent of the visual simulation, even with large scaling factors. Doty, Heintzman, Steedman and Schiffler (1969) describe one attempt by the United States Air Force at designing a model system to overcome the problem of limited size. This new system was called the *SMK-22 Visual Attachment*. Instead of using a fixed model, the model was attached to a flexible belt mounted between two rollers oriented horizontally, one located above the other. By rotating the rollers, the model would move vertically in an endless loop, thus creating the illusion of linear motion. A black and white video camera was mounted on gimbals adjacent to the belt, and the images from the camera were displayed on a rear-projection screen in the simulator cockpit. Changes to controls in the simulator would translate to scaled-down motions of the camera. With this arrangement, it was anticipated that the fidelity of visual presentation would be increased by including the simulation of rapid linear motion. Doty, Heintzman, Steedman and Schiffler (1969) report that although the system functioned, "The SMK-22 Visual Attachment had extremely poor acceptance in the field" (p. 11). Besides being prone to mechanical problems, the authors report that image quality was poor in general because of limitations of the equipment and because of the poor resolution of video systems of that time. Kelly and Parke (1970) also note that most video-based model projection systems, "lack adequate illumination, adequate resolution and adequate field of view" (p. 133). This view is also shared by Huff and Nagel (1975). Parrish (1969) reports that poor resolution and illumination of many CRT-based simulator visual systems cause eye fatigue. To overcome these limitations, new motion picture projection systems were devised using digital computers to control some of the optical functions. One of the most successful of these is a system developed by the successor to the Link Company, Singer-General Precision.

Called *VAMP*, an acronym for *Variable Anamorphic Motion Picture*, the system employs a series of projectors and lenses, controlled in part by a digital computer and partly by the actions of the simulator pilot, to project a moving image onto the windows of the cockpit directly (Kelly & Parke, 1970). The motion pictures for the VAMP system are photographed on 70 mm film using cameras mounted on the underside of helicopters. The height at which the helicopter flies as it approaches and/or leaves an airport is determined by the characteristics of the aircraft to be simulated. Kelly and Parke (1970) for example, state that when the motion pictures are taken for a simulation of a Boeing 707, the helicopter flies at 30 feet (9 m) above the runway, while motion pictures for a simulation of a Boeing 747 Jumbo jet are made at 60 feet (18 m) above the runway, these heights represent the approximate height of the actual aircraft cockpits above the runway. Although a two-dimensional image is photographed, changes made by the lenses create an illusion of perspective and three-dimensionality to the viewer. Specific weather conditions can also be simulated through the addition of filters (Kelly & Parke, 1970). While the realistic projection of an actual image improves the fidelity of a simulator's visual system, methods like VAMP also possess limitations. Kelly and Parke (1970) state that the major limitation "is that it [VAMP] still offers only a very limited angular excursion envelope so that... one gets a realistic view only if one stays in a very narrow path left or right" (p. 139). A solution to this problem is not easy with the technology used. Kelly and Parke (1970) note, "it's almost impossible to pre-record all the possibilities [of flight path variation] since one can't predict all the variables" (p. 139).

Although motion picture-based systems such as VAMP provided higher-fidelity images than most early video-based systems, developments in electronics and video technology soon resulted in image quality that rivaled that of motion pictures. The advent of high-resolution graphical systems in computers and high-capacity storage devices such as videodiscs, means that images can be stored and retrieved rapidly. The nature of such computer storage systems facilitates the rapid display of images that are not contiguous in a sequence. Most motion picture-based visual systems are incapable of displaying non-contiguous frames rapidly. Some computer systems are also capable of producing two and three-dimensional images artificially (Huff & Nagel, 1975). In consequence of technological developments, many recent simulator visual systems use either computer control and/or computer generation of images that are displayed on high-resolution CRT displays in the cockpits of the simulators (Virtual Prototypes, 1988a; 1988b). Besides displaying the environment surrounding the simulator, some visual systems, especially those installed in simulators designed to simulate a number of different aircraft, also display representations of the cockpit instruments (Huff & Nagel, 1975). Although concerns of fidelity can be raised, since video representations of an instrument may be different from its appearance in an aircraft, many large aircraft use CRT instrument displays (Virtual Prototypes, 1988a; 1988b). When the simulator is used to simulate such aircraft, then the displays maintain a high degree of attribute fidelity. In spite of the improvements made to video technology, it is contended by Blatt and Gum (1986) that further improvements to display image quality do not seem to be forthcoming given existing CRT technology. Other visual systems have been developed that enable the pilot to see particular displays without lowering his/her head to look at an instrument panel.

This new type of display is called *Head Up Display*, and is also known by the abbreviations *HUD* (Friedrich, 1986) or *HMD* (Virtual Prototypes, 1988b). Blatt and Gum (1986) state that the object of this type of display system is to, "portray only the instantaneous visual scene as seen by the pilot at any particular instant rather than portraying the total outside world regardless of where the pilot is looking" (p. 11-5). This feat is accomplished by specialized display apparatus housed within a flight helmet to be worn within the simulator. The apparatus, under the control of a digital computer, contains arrays of fibre optic cables that transmit images and infrared beams. By illuminating the eye with infrared light, in the manner of an oculometer, the computer is informed of where the pilot's eyes are pointing. The image appropriate to that location is retrieved and transmitted to the helmet. By means of small light-valve projectors, the image is passed through other fibre optic cables within the helmet and is displayed on two clear plastic panels mounted on the front of the helmet, so that they are located several centimetres away from the eyes of the pilot (Blatt & Gum, 1986). According to Blatt and Gum (1986) a slightly different image is shown for each eye, "to match human psychophysical performance" (p. 11-5). By projecting images taken from slightly different perspectives, an illusion of three-dimensionality is created, thus creating a *virtual image*. While Blatt and Gum (1986) report that a Head Up Display is being developed by the Canadian simulator firm CAE Electronics, Friedrich (1986) reports that a similar system, manufactured by the German company Dornier, is already in use by the *Deutsche Luftwaffe*. Helmets equipped with projection apparatus are being used with some video-type action games intended for entertainment purposes. While the principles of operation are similar to the Head Up Displays used with some aircraft simulators, the quality and complexity of equipment used for video games is likely inferior.

While recent developments in simulator visual systems have increased fidelity, the complexity of such systems combined with the complexity of other simulator systems can lead to losses of fidelity. Blatt and Gum (1986) note that one major problem is obtaining synchronization between the visual system and motion system. A lack of synchronization between these two cue systems may not only distract pilots using the simulator, but may also hinder the transfer of learning. Although flight simulators have undergone considerable changes since their initial use in the early twentieth century, simulators appear to be an integral part of many flight training and instruction programs. The apparent success of flight simulators as instructional devices has led to the development and use of simulators in other areas, both related to transportation and in environments that are completely different.

Other simulators for transportation training

Marine applications

In 1937, when sales of the Link Trainer to airlines and air forces began to increase, Link designed a simulator to teach the procedures of taking off, landing and navigating amphibious aircraft in water (Kelly & Parke, 1970). Called the *aqua trainer*, the apparatus consisted of a modified Link Trainer fuselage mounted on a hydrofoil powered by a small gasoline engine. The device was incapable of flying and could operate only in water (Kelly & Parke, 1970). Unlike the flight trainers described previously, the aqua trainer was designed to function in the real environment of the actual aircraft, and without physical restrictions of movement in that environment. In this manner, the simulator possessed a high degree of fidelity overall. In spite of its attributes, little interest was shown in this type of simulator and development was abandoned. Marine-based simulators were used for instructional purposes during the Second World War, however.

Attack teacher

Perhaps some of the most dangerous crafts to pilot and to survive in during the Second World War were submarines. While these craft can surprise enemy ships, and sink or damage them severely, submarines are vulnerable to attack from those ships, other submarines and from aircraft. It was considered essential, therefore, that crews be trained to attack with submarines both quickly and efficiently. It was shown to be costly both in human life and equipment to have submarine crews learn such skills through field experience (Young, 1953). At some point during the Second World War, the British Navy decided that a simulator to enable crews to develop and practice attack skills without risk to personnel and equipment was required to address this training problem.

A simulator was designed that occupied two floors of a training centre and required several people to operate it. The upper floor contained a plotting table, shelves containing scale models of ships, a table painted to simulate the surface of the ocean, and the top of a periscope (Young, 1953). The lower floor simulated the interior of a submarine, although Young (1953) states that the appearance of the control room bears little resemblance to control rooms on actual submarines. While the fidelity of such attributes appears to have been low, the operation of the simulator apparently possessed a high degree of fidelity. Once the crew is in place in the simulated submarine, the instructor, located on the upper floor, places a model on the table simulating the ocean. A radio command is given to the crew that a ship has been sited and that appropriate action should be taken. At this point, the top of the periscope is uncovered and the submarine crew may use the periscope to identify the ship. Additional information about the ship is reported, such as its speed and direction. This action forces the crew to make decisions about whether the ship is friend or foe, and if hostile, about how best to attack it. Prolonged hesitation results in the instructional staff on the second floor dropping lead weights onto the roof of the simulated submarine. The dropping of the weights signifies that the delay has resulted in the submarine being rammed by the ship or attacked with depth charges. If an attack is made within a reasonable time, then the instructional staff plots movements of the simulated submarine on the plotting table, based on the commands given to the engine room and to the helmsman by the commander (Young, 1953).

The paths of torpedoes are also plotted. The simulation may be prolonged by the appearance of additional ships and other submarines.

After the simulation ceases, the crew ascends to the second floor to view the path plotted on the plotting table and to see whether any torpedoes hit and sunk targets. Feedback on the tactics used are provided by the instructor. Young (1953) notes that the ease with which an attack could fail using the simulator, motivated crew members to consider the difficulties in performing an attack with an actual submarine, "your gloom would increase when you remembered that these model attacks were carried out in perfect visibility, ... and none of the navigational anxieties you were liable to have when operating in shallow water" (p. 113). While Young (1953) does not provide additional information about the attack teacher, it appears to have been used as an integral part of submarine crew training, since it addressed a particular perceived problem in the training of submarine crews. The use of the simulator likely did result in improved crew performance and fewer losses in action. It is likely that this type of simulator was developed further and modern versions are used by several navys at the present time.

Later marine craft simulators

While the process of learning to steer ships is not usually as critical a process as flying an aircraft, since fast decision making is usually not required, there are particular instances where this is not the case. Wagenaar (1975) notes that supertankers are, "the biggest man-machine systems ever built" (p. 440). The large size of these craft combined with their high capacity for substances potentially harmful to the environment means that errors in piloting can result in disastrous consequences that affect much more than the ship and its crew. While computer systems and radar can steer and guide supertankers in most instances, Wagenaar (1975) states that, "Law requires that in critical conditions (e.g. approaches to a harbor) these ships be steered by hand. Hence, steering a supertanker is a task people perform, and psychological limitations of all sorts may interfere with or even preclude satisfactory performance" (p. 440). The author also notes that the greatest difficulties to contend with when piloting a supertanker manually are the effects of inertia. Experience through practice is one possible way of addressing the perceived problem of how to minimize the likelihood of pilot error.

While it is not feasible to permit practice with actual supertankers, several solutions using simulators have been devised, some more successful than others. Wagenaar (1975) notes that some initial simulators used scale models of supertankers to permit the pilot to observe, and to feel through controls, the effects of inertia on the movement of supertankers. This approach is similar to some experimental visual display systems developed for flight simulators. Although the pilot is a part of the simulation, both in the flight and marine simulators, he/she is given a *God's eye* view of the situation rather than a *pilot's eye* view (Wickens, Haskell, & Harte, 1989). While an overall or God's eye view shows the concept of inertia to the pilot, the method creates problems that hinder the positive transfer of learning. Wagenaar (1975) states that performing manœuvres using scale models is easier than on a real tanker, "because of the quickened time scale. Even negative transfer of training from scale models was observed" (p. 441). The poor success of this type of simulator led to the development of full-scale simulators based on the principles inherent in flight simulators. Some of the first were designed in the Netherlands, because of the large number of supertankers that use its harbours.

After developing unsuccessful stationary versions, Wagenaar (1975) reports that satisfactory results were obtained with a moveable simulator. This device consists of a simulation of the wheel house (bridge) and a portion of the surrounding deck. This assembly is contained within a large cylindrical viewing screen measuring 20 m in diameter with a height of 10 m. This arrangement is similar to that used with the RCAF Link Trainer used to test a recruit's resistance to vertigo. The interior of the wheel house is appointed exactly like one in a real supertanker, except that the windows are positioned and shaped to prevent the ends of the screen from being seen. Image projection apparatus is located on the roof of the wheel house (Wagenaar, 1975). Two xenon arc lamps, one located above the other, provide illumination for some of the images to be projected. These images are located on a painted, translucent cylinder that revolves around the light sources. The lower light source projects images of coastlines, part of the sea and the sky, while the upper light controls brightness of the sky (Wagenaar, 1975). Landmarks and objects in the sea are created by the projection of light past a moveable model located at the end of a 2 m long support arm. A light source projects a silhouette of the model against the screen. Two wide-angle slide projectors display images of the front of the supertanker against the screen. A digital computer controls the projection equipment and also records the path of the supertanker during the simulation. With this apparatus, a pilot or shipmaster can practice or gain skill at manœuvering a supertanker manually. Wagenaar (1975) reports that it is possible for the control computer to monitor the heart rate, EEG, Galvanic Skin Response, and eye movements of the shipmaster during the simulation, provided that he/she remains seated. It is likely that this data is recorded for later analysis and review.

Although the simulator functions in a manner similar to some flight trainers, Wagenaar (1975) reports that there are limitations with the visual system, so that resolution is lost in some instances. The development of video and CRT-based systems in the United States by the Sperry Rand Corporation is noted. It is not known whether this system has been developed beyond the experimental stage. Like aviation training, particular problems perceived in the training of shipmasters led to the creation of instructional simulators.

Some navys use simulators to teach crews operational procedures of new or re-fitted vessels (Miles, 1975). One example is the Royal Canadian Navy, which uses simulators of its new frigates to train crews ("Officers learn", 1988). Besides teaching crews procedures specific to the new craft, the navy chose to use simulators to minimize the potential effects of an inexperienced crew learning with an actual frigate. The American crew who shot down an Iranian passenger aircraft, mistaking it for an attack of a hostile fighter, is cited as an example of this phenomenon ("Officers learn", 1988). Each simulator consists of a replica of the bridge, complete with the hardware found in the actual frigate. A visual simulation system is provided, but motion simulation is absent. No reason is given why a motion system was considered unnecessary It is stated that, "the equipment [the simulator] is shielded from electronics eavesdropping by lead walls and ceilings" ("Officers learn", 1988). While it is unlikely that lead is used, since it is ferrous metals that impede electro-magnetic waves, it is possible that security constraints prevent the inclusion of a motion system. Although much detailed information about the simulators is unavailable, it is known that they are used to provide crews with experience both in normal operations and in contending with attack and other emergency conditions. While most simulators for marine applications appear to be constructed from the basis that simulators are representations of actual events or occurrences, there are other marine simulators designed from a different basis.

Psychomotor simulators of abstract concepts

It was noted at the outset of this chapter that there are two major theoretical bases of simulators; the simulation of an actual situation, or the simulation in tangible form of an abstract idea. It may be found that simulators from the second basis coincide with actual situations. When such simulators are designed, however, empirical information is lacking, so assumptions in the form of abstract ideas are made. The space flight simulators noted previously are examples of simulators designed from the second basis. Similarly, some simulators for marine training have also been developed from this basis.

Although individuals may receive training in one environment, there is no guarantee that the training will be transferred successfully to a different environment (see Guthrie, 1942). This consideration faced designers of a deep sea search vehicle. The designers required a method of ascertaining whether problems in transfer of training and/or performance problems would occur in the new and untried vehicle (Rosencrantz & Blair, 1969). Following the example of NASA in using simulators to teach some assumed elements of space travel, a simulator of the proposed deep sea search vehicle was designed and constructed. Composed largely of fibreglass, the simulator was prepared to resemble the interior of the actual vehicle (Rosencrantz & Blair, 1969). While the simulator did not possess a motion system, a moving model video image system was used, similar in design to examples used with some flight simulators. Rosencrantz and Blair (1969) note that the endless belt was oriented horizontally rather than vertically. With this arrangement, target objects could be placed on the belt for discovery and identification by the simulator crew.

While it was found that crews could apply skills learned elsewhere successfully in the simulator, factors such as fatigue, which did not appear before using the simulator, forced procedural changes to be made in the operation of the actual craft. Simulating complete missions also led to design modifications of the actual craft (Rosencrantz & Blair, 1969).

Although several instructional simulators for marine applications have been described and discussed, it appears as though simulators are not used as extensively in this area as they are for flight training. While a single explanation for why this is so is not immediately apparent, it appears that most simulators are either designed or used when there is a perceived need for them. It also appears that instructors do not abandon one instructional method for another in anticipation that the new method selected will be better.

Simulators for railroads

While the first flight simulators appeared about 1910, there is evidence to show that simulators were also being used at that time to teach both skills and concepts of railroading. The special convention issue of the 1909 *Electric Railway Journal*, for example, describes instructional methods used by several American street railroads. Several concerns used simulations of streetcar electrical and brake systems to provide initial instruction to new staff. Unlike many flight simulators that are intended to teach psychomotor skills, it appears that most street railway simulators demonstrate the concepts and principles of streetcar operation tangibly. In this manner, new staff may acquire knowledge of what their actions do to the systems they are operating. Instructional simulators were also used by other modes of rail transportation. The Seattle Electric Company, for example, operated a system of streetcars powered by a moving cable located beneath the surface of the streets (cable cars). Initial instruction in operating the cable grip inside the cable cars was provided on platforms equipped with an actual grip mechanism (*Electric Railway Journal*, 1909). Although the platforms possess low fidelity when compared to an actual cable car, the grip mechanism and its interaction with the cable possessed extremely high-fidelity, since the actual equipment was used. The goal of the simulator was to provide instruction and experience in grip operation only. The fidelity of the remainder of the cable car, therefore, was superfluous to the instructional goals of the simulator. There was an evident need for instruction by simulator before novice gripmen could be permitted to practice with actual cable cars. Hilton (1982) reports that in particular instances, such as where one cable line crosses another, mistakes in manœuvering the grip result in severe damage to the cable car plus the halting of both cable systems. Extensive field repairs are then necessary before service may be resumed on either cable circuit. Although most cable railways have disappeared, the principle of using simulators for instruction in response to evident need continues.

The inability of some rail transportation systems to accommodate on-the-job training also creates a need for instructional simulators. As early as the 1920s, parts of the London underground railroad system were so busy that an elaborate system of block signals was used to control train movements. The complexity of the signal system was thought to be too dangerous to permit trainee motormen to operate trains without gaining practical experience with the system first. Observational learning, through having the trainee travel with an experienced motorman, is one way of instructing novice motormen. Another method of instruction, one that requires interaction by the trainee, is to use a simulator. Lee (1973) includes a photograph of the signal simulator used on the London Underground. The apparatus consists of a model section of underground railway with miniature signals. It is likely that the trainee operates a miniature train through the model. An instructor probably alters the signals to expose the trainee to a variety of conditions. The small model, while possessing low fidelity, does permit the principles of the signal system's operation to be demonstrated, by providing the trainee with a *God's eye* view. As noted in previous sections, there is evidence to show that low or a negative transfer of learning may result when simulators of this type are used to instruct particular psychomotor skills. It is not known how successful the underground simulator was or when its use was discontinued.

The success of air flight simulators in addressing perceived needs of pilot training encouraged users of other transportation modes to consider using simulators for instructional purposes. For this reason and because problems with existing instructional techniques were identified, the American railroad, Atcheson, Topeka and Santa Fe (referred to generally as Santa Fe) asked the Link Company to design and produce a locomotive simulator in the 1960s (Kelly & Parke, 1970). Modeled on a General Motors model SD-45 diesel locomotive, the simulator duplicated the interior configuration of the cab exactly. A hydraulic system simulated the lateral and vertical movements experienced in a travelling locomotive. Linear motion was not simulated physically. Instead a visual system was used. Visual information is provided by a film-based system similar to the VAMP system used with some flight simulators. An air compressor provides a supply of air to simulate air-based sounds, while electronic circuits generate other sounds. Both normal operations and emergency manœuvres can be simulated with this apparatus (Kelly & Parke, 1970). The latter feature is especially important, since duplication of some emergency conditions with actual trains, such as an emergency brake application on a 100 car freight train travelling 60 miles an hour (100 km/h) usually results either in extensive equipment damage or in a derailment. In the same manner of most flight simulators, locomotive simulators enable new and experienced engineers to develop and practice skills necessary for safe and efficient operation.

Some railroads such as the Canadian National, use simulators as an integral part of training and re-training. This approach is thought to diminish accidental damage to new locomotives that possess systems requiring different operating procedures (personal communications with CN Rail, 1991). Making a mistake on a simulator may result in a sequence of objectionable noises and criticism from the instructor. The same mistake made on an actual locomotive could result in damage to the locomotive requiring extensive repairs. While the locomotive is being repaired, it cannot pull trains, so it becomes a financial burden rather than an asset to the railroad. Besides damage to equipment with consequent loss of revenue, procedural errors could result in the loss of life, both of railroad employees and private individuals in proximity of a mishap. As with flight instruction, locomotive simulators address a perceived instructional need. Locomotive simulators possess sufficient fidelity overall to ensure a positive transfer of learning while being less costly to use than an actual locomotive. The factors of safety, positive transfer of learning and cost effectiveness also prompted the development of simulators for driver training of rubber-tired vehicles.

Driving simulators

Simulators for teaching driving skills seem to have first appeared by the early 1950s, based on the principles of the Link Trainer (Fox, 1960). Most of the early driving simulators do not resemble the operation of the Link Trainer, however. The *Auto Trainer* designed by the American Automobile Association is an example. Fox (1960) describes the Auto Trainer as, "a driver's compartment with regular controls, a continuous canvas belt (mounted in front of the compartment) which moves in response to the accelerator and brake, and a miniature car which can be steered over a roadway painted on the belt" (p. 51). Electric motors move the belt, which contains miniature signs and changeable traffic signals. This arrangement creates the illusion of linear motion, although the fidelity is at a low level. An instructor can modify the simulation by causing the aspect of the traffic signal to change and he/she can also change road signs and add obstructions to the belt, such as another model vehicle. In this way, the Auto Trainer is designed to be a self-contained unit intended for individualized instruction (Fox, 1960). Unlike most flight simulators, this driving simulator uses a *God's-eye* view of the driving environment rather than a perspective based on the field of view of an operator of an actual automobile. Although it is claimed that manœuvres such as parallel parking, stopping and changing gears may be learned from this simulator, the simulator lacks fidelity in providing proprioceptive cues. Fox (1960) concludes, on the basis of several studies investigating the efficacy of the Auto Trainer, that the ability of individuals to transfer skills learned on a simulator is dependent in large part on the design of the simulator and that other driving simulator designs may lead to a greater positive transfer of learning. This view is similar to that of Wagenaar (1975) who contends that simulators using scale models may hinder the transfer of learning to the actual situation. Whether such findings influenced the designers of driving simulators is not known. A different driving simulator design appeared by the late 1950s, however.

The design of the Auto Trainer makes it difficult to use when a class or group of individuals are to be taught simultaneously by one instructor. While it is possible for each student to work independently, this arrangement is difficult for instructors to monitor, so it is possible for students to make mistakes repeatedly before they are corrected. The design of most subsequent driving simulators, therefore, retain elements of individualized instruction while also requiring uniform progress of the group through a lesson or an exercise. Although details differ, the basic design of this type of driving simulator is common to most manufacturers.

Driving simulators designed to be used for group instruction and practice consist of a simulation of the driver's position of an automobile, bus or truck and a housing for control and feedback circuitry plus a speaker or provision for headphones. The entire simulator rests on a support base that may also contain apparatus for motion simulation. Figure 97 shows the typical appearance of a driving simulator unit designed for use in conjunction with other units. The particular simulator shown is of an automobile configured with an automatic transmission. Versions of such simulators are manufactured for use by disabled persons. Such driving simulators omit the chair and substitute hand controls for the pedals (Doron Precision Systems, 1990).

Additional equipment is required before driving simulators of the type shown in Figure 97 may be used. Instead of a moving model system, a video or a film-based visual system is used. In most instances, simulator units are located in an area equipped with projection apparatus and a screen located so that the projected image will not be obscured either by simulator units or the heads of the individuals using them. Some portable installations mounted in truck-hauled vans or buses, much like the arrangement designed by the Pennsylvania State University for portable IBM 1500 systems (see Chapter VII) place CRT monitors on the top of each simulator unit instead of using a projection screen (Doron Precision Systems, 1990). Manœuvres requiring reversing may be learned and practiced with the aid of two mirrors mounted on the back of each chair. The mirrors enable the student to look backwards while still being able to see the screen image of the road or parking space.

Each simulator unit is connected through wires to either an electro-mechanical or computerized tabulation and control unit. The unit is designed to monitor the actions of each simulator station and to compare the actions to information encoded on the film or

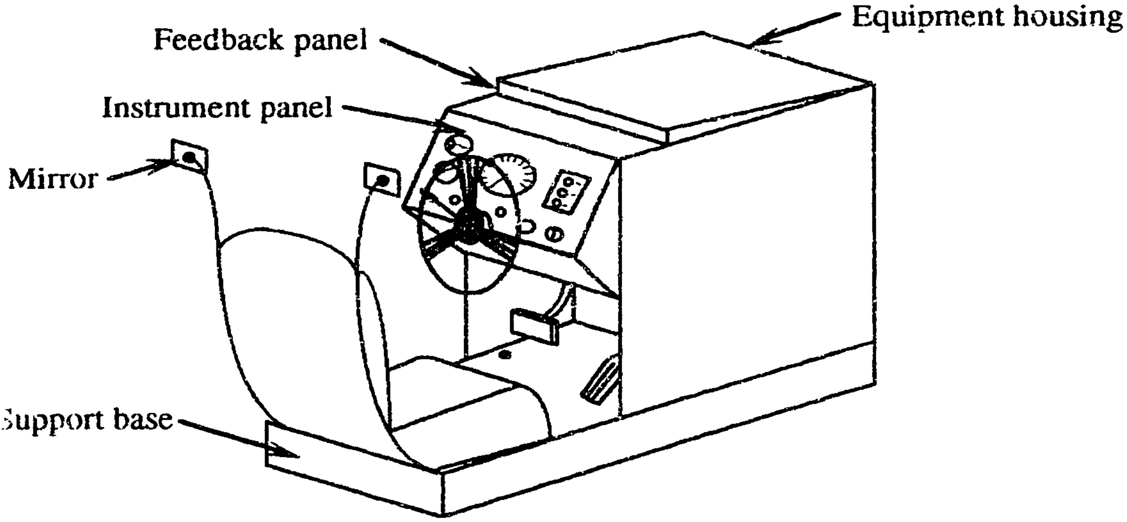


Figure 97. Typical appearance of a driving simulator unit

videotape providing the visual cues. Deviation from acceptable parameters by any simulator unit results in the tabulation and control unit performing several actions. The nature of the error is identified and recorded as a light on the instructor's panel, indicating the unit making the error and the type of error. At the same time, a feedback light is illuminated on the feedback panel of the offending simulator station. The light provides an indication to the student of what was done wrong. Two counters are also increased by one increment. One counter records the total number of errors made by all active simulator units during the current simulation. The other counter, assigned to the simulation unit that made the error, is also advanced by one increment. That counter indicates the total number of errors made by that particular unit during the current simulation. Most tabulation and control units also contain the ability to print out information as a report (Doron Precision Systems, 1990). Some tabulation and control units are able to introduce particular conditions to the simulator units such as icy or wet road conditions and the effects of heavier or lighter loads in the vehicle. One control unit manufactured by Doron Precision Systems is able to affect the steering and brakes, so that the simulator units simulate the effects on driving caused by specific levels of blood alcohol (Doron Precision Systems, 1990). It is anticipated that by having the simulator act in a *demonstration mode*, the student will perceive through observation and interaction, the practical difficulties and dangers of operating a motor vehicle while intoxicated.

As with the other types of simulators mentioned to this point, there is no consensus as to what degree of fidelity overall should be present in driving simulators. Some researchers such as Fox (1960) contend that a high level of fidelity of driving simulators is not necessary, since the presence of too many cues or events tend to distract the learner. While it is has been shown previously that a preponderance of stimuli can distract the learner from the intended task, it has also been shown that simulator complexity and fidelity are dependent more on the intended instructional goals of the simulation rather than on consideration of fidelity as a discrete element without context.

Driving simulators may be designed for the initial practical instruction of individuals who have never driven, or they may be designed to provide instruction in specific techniques to individuals who are experienced drivers. If a driving simulator is intended for use by inexperienced drivers, for example, then stimuli such as motion and sounds may hinder the learning of the intended skill. In such instances, high fidelity overall may be detrimental to the positive transfer of learning. Other stimuli can be added gradually as skills improve, to diminish the differences between the simulator and the actual vehicle.

Conversely, a driving simulator designed for experienced drivers may hinder learning if particular cues expected by the driver, such as particular motions or sounds, are absent. The absence of expected stimuli or cues may result in the driver experiencing *cognitive dissonance* (Festinger, 1957).

No matter what degree of fidelity is used, therefore, simulators may not be effective if their instructional goals are not defined, recognized or accepted. For example, Fox (1960) states, "Manufacturers and users of the device [driving simulators] as well as others may expect a level of performance which is beyond the capability of *any* teaching device" (pp. 48-49). This consideration is especially important for educators in schools who, as is shown in previous chapters, are sometimes encouraged to use instructional devices without being informed about their limitations and attainable instructional goals. It is also important to recognize that simulators of actual events or processes frequently comprise only a portion of the instruction in a given area. While skills learned on a driving simulator may be transferred to an actual motor vehicle, it is doubtful that the individual driving the motor vehicle will possess much proficiency at driving until considerable practice takes place. Simulators should not be intended as a substitute for other modes or types of instruction, although using simulators may reduce the practice time required to gain desired proficiency on the actual device (Fox, 1960; Holstein, 1965).

The deployment of driving simulators, like most other instructional devices, is in large part dependent upon finances. Although the cost of driving simulators has increased since the 1950s, cost was an important consideration at that time as well (Fox, 1960). The high cost of driving simulators combined with a desire to keep disbursements to a minimum prompted several American automobile insurance companies, such as Allstate and Ætna, to underwrite and sponsor the use of driving simulators in some public schools in North America (Holstein, 1965). Although some corporate sponsorships have ended, some schools continue to use driving simulators as part of driver training programs (Saskatchewan Department of Education, 1975). More extensive use of this type of simulator is made by large companies and by military organizations in many parts of the world (Miles, 1975; Doron Precision Systems, 1990).

Other simulators for psychomotor skills

Gunnery simulators

Although the military has used simulators at various times throughout history, such as the quintain and the Link Trainer, the adoption and use of simulators by military organizations usually occurs after a need is perceived by the upper administration. Such needs can be based on a variety of factors including: current circumstances, such as war; the design of the equipment; studies of the efficacy and efficiency of pedagogical methods used; the danger to personnel and equipment posed by existing instructional methods; and the cost of instructional methods. Some of these factors motivated the United States military to select new methods of training particular personnel in the operation and firing of particular types of fire arms. Fox (1960) states, "The influx of recruits and the scarcity of training weapons made the use of synthetic devices [simulators] mandatory" (p. 10). The deployment of particular weapons also required the use of simulators. Fox (1960) notes that with ærial gunnery, "Because of time, cost, and danger, the task requires that training devices be used in learning the necessary skills" (p. 26). Besides having to shoot accurately at a target, the gunner must compensate for movement of the target and the movement of his/her aircraft. An added element is that the target usually shoots back at you.

While it has been shown in this chapter that simulators are capable of simulating many situations, some with high-fidelity, most are unable to engender in users the emotion and anxiety experienced in the actual situation. While some medical simulators, such as Sim One can *expire*, the user is cognizant that it is an inanimate object, not a real human being that has ceased to function. Thus, the actions and the performance of the user may be different from an actual situation, where emotion and anxiety may be factors. The awareness that the simulator is different from the actual situation can be compensated for in part by imposing conditions on the simulation, for example a failing grade if Sim One expires. While such methods might cause anxiety in some users of the simulation, the anxiety is contrived and it may not be analogous to what is experienced in the actual situation. Similarly, learning ærial gunnery on a simulator may not be easily transferrable to actual practice, given that the anxiety and emotions of realizing that fire is being directed towards you might interfere with the performance of skill. This concern is similar to Guthrie's rejection of the formal discipline theory of transfer of learning (Guthrie, 1942; Guthrie and Powers, 1950). The formal discipline theory of transfer of learning maintains that once a behavior is learned, it may be performed later, the environment being minimal in affecting the behavior. Guthrie's theory, like Thorndike's (1906) identical elements theory of transfer, contends that the transfer of learning is dependent upon the degree to which a new environment resembles the environment where the learning took place. While it may be contended that a simulator with high-fidelity resembles the actual situation or object closely, not all elements of the environment are necessarily simulated. The difficulties in simulating the emotional and anxiety elements in simulators continues to be a problem that may affect the transfer of learning.

Several versions of aerial gunnery simulators were constructed by companies such as Link, Sperry and [illegible] 1960). Initial versions, such as one constructed by the Sperry Gyroscope Company, consisted of a simulated gun turret, a gun simulation equipped with a photo-electric cell, and a cam-controlled projector that could display a spot of light randomly against the ceiling of the room housing the simulator (Hobbs, 1947). The object of the simulation was for the user to sight the gun on the projected spot of light and to squeeze the trigger. If aimed correctly, the photo-electric cell on the gun would capture enough reflected light to close a circuit. The circuit advanced a counter that records the total number of *hits*. The task was made more difficult by the cam arrangement of the projector, which caused the spot of light to move randomly about the ceiling. Feedback to the student was provided by a sounder located within the recorder. The sounder could be set to function each time the trigger was squeezed, thus indicating every instance that a shot is fired, or it could be set to function only when the counter advanced, indicating hits. Hobbs (1947) states, "The sounds of shots being fired or hits being scored enhanced the students' interest in the practice" (p. 152). As well as functioning as feedback, therefore, Hobbs (1947) contends that the sound of shots also motivated the students. This element is similar to what many video games use to sustain motivation. While the Sperry simulator provided interactive practice, the projected light spot possessed low fidelity both in appearance and in action. Although an enemy aircraft tends to move from side-to-side to avoid being hit, it also tends either to advance or retreat. Neither of these latter two motions could be simulated with the Sperry unit.

To increase fidelity of target motion, other simulators were designed that used modified targets and feedback mechanisms. One version, depicted in Roberts (1943) uses miniature models of aircraft moved by an overhead pulley and wire arrangement, while two versions of a simulator made by DeVry, use elaborate models and motion pictures to simulate the visual field of a gunner (Hobbs, 1947). It is not known how accuracy was measured and feedback provided in these simulators.

In spite of extensive training using such *flexible gunnery trainers*, Taylor (1947) notes, "fire control devices frequently failed to direct gun fire with the accuracy which was expected from the mathematical and mechanical characteristics built into the equipment" (p. 87). The apparent discrepancy between training methods and actual field performance resulted in considerable study by psychologists. After investigating the possibilities of mechanical problems and major instructional flaws, it was concluded that most of the problem stemmed from poor ergonomic design of controls coupled with the anxiety-inducing effects of combat (Taylor, 1947). Besides modifying equipment, instructional methods were reëvaluated. Instead of recognizing that the simulators used for training lacked the capacity to simulate the anxiety-producing elements of the actual situation, Taylor (1947) states that it was concluded that the training methods used were ineffective because a complex skill, comprised of many discrete skills, was being taught at one time. Like Gagné subsequently, Taylor (1947) contends that, "in many military tasks the operations required are a series of simple motions arranged into complex sequences which are repeated frequently" (p. 89). An atomistic training program was advocated, so that each discrete motion could be performed *automatically*. No indication is provided as to how the discrete motions are to be concatenated to create a cohesive, single motion. Moreover, little consideration appears to be given as to how this single motion is to be performed in a hostile, anxiety-producing environment, when instruction and practice centres on discrete elements of the entire motion, taken out of context. While Taylor (1947) notes that research on the efficacy of different instructional methods is not complete, it is important to note that Kelly and Parke (1970) report that later aircraft gunnery trainers use high-fidelity, computer-controlled visual systems that require interactive tracking by the user.

Some current gunnery trainers maintain a high [illegible] visual fidelity, but do not maintain high-fidelity overall. The reason for this [illegible] instructional goals of such simulators is to enable experienced individuals to maintain particular skills and procedures. One example of this type of simulator is the M-60 *Tank Gunnery Trainer*, manufactured by Perceptronics of Woodland Hills, California and used by the United States Army. The simulator is a wall-mounted unit, resembling an arcade game, that possesses two handles, a viewing objective, switches for firing control, and a loudspeaker (Zawacki, 1983). Targets are visible through the objective and the gunner uses the controls to aim and fire the simulator. Sound effects are generated electronically and are reproduced in the loudspeaker. Feedback is visual, and is observed through the objective. Zawacki (1983) states that the simulator addresses a perceived need,

> Since the costs of firing one round of main-gun tank ammunition is over $125.00, this expense can reach astronomical proportions when all of the tank gunners of the U.S. Armed Forces must rely on live fire exercises to maintain a minimum degree of skill proficiency. (p. 23)

Although the simulator serves a pedagogical purpose, the primary need for it is financial rather than pedagogical. It is also stated that the simulator presents enemy tanks rapidly, to increase the speed at which tank gunners attack enemy tanks. Zawacki (1983) contends that this feature, "creates a highly motivating training standard" (p. 24). While the low fidelity overall may be explained by knowing that the simulator is intended for use by experienced tank gunners, the introduction of new learning in the form of more rapid firing, may not be easily transferrable to actual combat situations. Although the M-60 Tank Gunnery Trainer is being used as an instructional device, Zawacki (1983) notes, "The use of arcade-style training devices is still under evaluation, but the initial results have proven to be highly positive" (p. 24). Performance with actual tanks in combat will likely reveal whether this type of simulator and its intended purpose are valid.

Radar simulators

While most simulators arise from a perceived need, such needs are not always the reduction of danger to personnel and equipment during training. In some instances, instructional and practice time on the actual equipment is unavailable. In such cases, therefore, simulators are usually indistinguishable in external physical appearance from the actual equipment, although the operation of the simulator can be altered for instructional purposes. Examples of this type of simulator are those manufactured for radar training. Like most of the simulators described in this chapter, simulations of radar consoles are used primarily by the military (Fox, 1960; Parrish, 1969). While many such simulators are deployed in training centres, some are installed in their intended environment, such as on board ship (Parrish, 1969). Although external appearances differ among radar console simulators, most operate in a similar manner. Most contain a CRT that presents an image of the scanning beam and bright spots representing objects of material and size sufficient to reflect radar waves. The bright spots are sometimes referred to as *pips* (Lindsley, et al., 1944; Fox 1960). Real CRT's are not used in radar simulators, since actual radar waves are not used. Instead, simulations of the scanning beam and pips are projected onto the back of a ground glass screen representing the CRT (Lindsley, et al., 1944). A cam, located inside the simulator and rotated by an electric motor, causes the projection of a pip or pips to move around the screen in a pre-determined pattern. Up to eight different starting points on the cam can be used and the direction of travel may be reversed. In these ways, the illusion of many different patterns may be created with a single cam. Other cams may also be used (Lindsley, et al., 1944). The simulator is intended to provide practice in tracking pips. The student does this by aligning a hairline with the pip. The hairline is moved by the student turning the knob of a variac autotransformer. The varying voltage created by the movement of the knob alters the voltage reaching a Direct Current motor driving the hairline. The voltage is also fed to a synchronous motor connected to the travel of the cam follower. Deviations from the pip by the hairline create a voltage difference in the synchronous motor. This voltage difference causes a counter to advance by one increment each time that the hairline deviates from the pip. If the hairline remains away from the pip, then the counter is incremented after a time interval determined by the instructor (Lindsley, et al., 1944). The instructor may also add stimuli to the simulation once the student's proficiency improves. Fox (1960) notes that visual *noise* in the form of a double image or background static may be added by the instructor to make tracking the pip more difficult.

Lindsley, et al. (1944) state that individuals using radar simulators for initial radar tracking performed no better than individuals who learned on the actual equipment. Fox (1960) suggests that this finding means that a radar simulator, "is not a valid device for practice" (p. 29). This may disputed, in view of the instructional goal of the simulator, to provide instruction in radar tracking when actual equipment is unavailable. In this instance, the simulator is a valid instructional device, since it is able to provide instruction at a level equivalent to instruction on the actual radar set.

Fox (1960) reports that other types of radar simulators have been designed for instructing specific skills, such as radar scope interpretation. Most simulators of this type project motion picture images on the ground glass rather than trying to simulate specific traces through mechanical means (Fox, 1960). Some recent radar simulators, designed for naval applications, are computer-controlled devices designed to be installed on ships. One example is the *Shipborne Radar Trainer*, manufactured by Solartron Simulation of the United Kingdom (Solartron Simulation, 1985). This company is descended from the concern started by Gordon Pask in the 1950s for the manufacture of teaching machines. Unlike earlier simulators that were separate units contrived to resemble actual equipment, the Solartron simulator is a micro-processor-controlled device that generates simulated radar images on the ship's actual radar equipment. By having the students use the actual equipment, it is contended that the effects of elements likely to hinder transfer of learning, such as fidelity, are minimized. While the simulator may be controlled by an instructor, it may also operate without a human instructor. A built-in hard disk can store simulations prepared either on land or on board ship. Feedback is provided to students after the simulation sequence is completed, unless an instructor wishes to intervene and interrupt the sequence (Solartron Simulation, 1985).

Simulations of computers

Many mainframe computer systems require special operating and programming procedures. While such skills may be taught using the actual equipment, using the machines for instructional purposes limits the computing power available for the primary tasks intended for the system. A need existed, therefore, for a simulation of the computer system that could be used as an instructional device. One example is the simulator designed by IBM for its System 360, model 30 computer ("Simulation in training", 1966). Made to resemble the console of an actual System 360 computer, the unit was designed to be connected with up to five other such consoles, either to a single System 360 computer or to a 1400 series computer ("Simulation in training", 1966). The simulator is used as a teaching aid for training operating personnel. With this arrangement, up to five individuals can receive simultaneous instruction. The design of the simulator permits each individual to perform different operations on the console ("Simulation in training", 1966). It is not known how successful this approach was, or for how long this type of simulator was used for training computer personnel.

Simulators for psychomotor sports

Not all simulators for instructing psychomotor skills are designed for the military. The advent of micro-computer control has facilitated the inexpensive production of simulators for various sports requiring psychomotor activities. Electronic golf course simulators are noted in the section on computer-controlled simulation games. It is also noted that there is a fuzzy line separating entertainment from instruction with this type of simulator. The line is more clearly discernible when considering other simulators for sports.

While water skiing is a form of popular entertainment in much of North America, enjoyment is in large part dependent on skill. In northern areas of North America, the climate is too cold for several months of the year to permit water skiing practice. To practice during such times requires an individual either to travel to a warmer location, abandon the notion of practicing, or obtain practice using a simulator. One example of such a simulator consists of a large water-filled fibreglass tub containing a number of water jets fed by a circulating pump. The tub also contains a cross-seat and a means of holding a number of tow ropes ("Outdoor innovations", 1990). Manual or electronic circuitry controls the velocity of water leaving the jets. Individuals inside the tub put on water skis while sitting on the cross-seat. Once the skis are in place and the tow rope is held, the jets are turned on. The movement of water past the skis will lift them in the water. In this way, a simulation of water skiing is obtained without requiring linear motion of the participants. Skiers are able to practice turns and other manœuvres. Although some users report that the simulator seems to possess a high degree of fidelity overall, it is not known if a high degree of transfer of learning occurs from the simulator to actual water skiing.

Like water skiing, particular types of angling may be practiced only while climatic conditions permit. Some anglers desire to improve their skills both through practice and by receiving instruction. Much instruction in angling consists of books, video presentations and films that assume that the learner will be able, through observational learning, to emulate the methods demonstrated. More interactive forms of instruction are either expensive or unavailable. The need for interactive instruction is addressed in part by a simulated stream that may be stocked with fish ("Outdoor innovations", 1990). Besides permitting practice at stream fishing during winter, stream simulators may be located within towns and cities where angling experts can give lessons, using the stream simulator as a teaching aid. The high fidelity of the simulation overall by using real fish, likely facilitates the transfer of learning from the simulator to an actual stream.

Although rock climbing is considered a form of entertainment by some individuals, special skills are sometimes required to ensure a successful climb. As with the other sports mentioned already, climatic conditions and accessibility to a suitable environment may prevent regular practice. An added difficulty is ensuring that practice takes place in a location where the effects of a fall will not be severe or fatal. Rock climbing simulators have been devised to address these instructional needs. One example of this type of simulator is a cast concrete panel that is mounted vertically on a high wall. The panel consists of a rough textured surface resembling the rock face of a mountain. Fidelity is diminished somewhat by the inclusion of cast hand and foot holds in parts of the panel. It is intended that mats and/or nets be placed beneath the panel to cushion falls. Besides learning and practicing climbing skills, this type of simulator may build confidence in climbers. There does not appear to be experimental evidence to show whether there is transfer of learning from a rock climbing simulator to actual outdoor climbs. While it is likely that there are other simulators for sports requiring psychomotor skills, the examples provided show the diversity of types and the range of complexity of such simulators.

Simulators for teaching concepts and principles

Examples are presented at the outset of this chapter of simulators that present a tangible representation of an idea or concept. While such simulators are useful for conveying purely abstract ideas and concepts, there are other simulators that demonstrate other ideas and concepts inherent in actual systems and objects. The logic simulator is one example of such a simulation. While many of the simulators discussed to this point are concerned with imparting particular skills to the learner, the instructional goal of some other simulations is to teach particular principles of an actual system or object. Although the effects of the principle or concept are visible, the concept or principle itself is not immediately apparent, since concepts and principles are abstract.

Simulators of inherent concepts and principles of actual objects or systems typically use symbolic representations of the concrete objects. While this characteristic may be criticized since it diminishes both attribute fidelity and fidelity overall, it must be recalled that the instructional goals of such simulators does not usually include a knowledge of the practical operation of the object or system. One example of such a simulation is called *STEAMER* (Wenger, 1987). Steamer is a schematic simulation of a ship's steam-powered propulsion system, created on a CRT monitor by a microcomputer program. Although the simulation is designed to be used by engineers that will eventually operate actual ship board steam propulsion systems, the instructional goal of the simulation is to instruct only the principles of the propulsion system, not the practical skills for operating it. In many respects, the fidelity of such simulations is low, both in the appearance and attributes of system components and in the scale and spatial layout of the system. Wenger (1987) contends that the low fidelity of these aspects is of little significance in the simulation, since the element of *concept fidelity* is most important. Wenger (1987) states, "STEAMER's simulation is meant to reflect less an exact physical model than a mental model as used by an expert" (p. 84). It is likely, given the instructional goal of the simulation, and the apparently high level of concept fidelity, that students will learn the principles of operation underlying the propulsion system. It may be contended that by providing instruction in the principles and concepts underlying a skill or process, then mastery of that skill or process will be facilitated by the prior knowledge of the abstract principles or concepts. Other simulators of the sort that demonstrate the principles and concepts inherent in actual objects and/or systems include: SOPHIE, an acronym for *SOPHisticated Instructional Environment*, is a simulation of electronic faults using English sentences, requiring the student to employ logical concepts of electronics to solve the problems; MOLGEN, a simulation requiring the user to design experiments related to the study of molecular genetics; the British Royal Navy's *Tactical Trainers*, computer-controlled simulations of naval engagements used to teach the principles of naval tactics; and the Xenograde system designed by Carl Bereiter, a simulation of systems that can be modified by the user, so that the underlying theories of operation may be learned through discovery (Wenger, 1987; Pea, 1984; Miles, 1975; Merrill, 1988).

In spite of the large numbers of simulators devised for all sorts of instruction, few simulators are used in the instruction of educators destined for primary and secondary schools.

Classroom simulators

While some simulators are used as instructional devices in schools to address perceived needs, for example driving simulators and simulations of concepts in areas such as physics and electronics, it is rare that a need has been perceived for simulators to instruct prospective teachers. Such simulators were designed when a need was anticipated. By the beginning of the 1960s, there was an apparent shortage of teachers in many schools in the United States. This situation was interpreted by some university-level educators as meaning that prospective teachers might not be able to obtain sufficient supervised teaching practice before completing their programs (Kersh, 1961). To address this apparent problem, personnel at the Center for Research on Teaching of the Oregon State System of Higher Education in Monmouth, Oregon, developed a simulation of a classroom. Called the *Classroom Simulator*, the apparatus was installed in a room that possessed dimensions similar to most typical classrooms of the time. The simulator consists of a rear projection screen measuring six feet wide by eight feet high (1.8 m X 2.4 m) placed across the room a few metres away from the front. Between the screen and the front of the room is a control console where the instructor sits. A signal panel located adjacent to the control console, permits the instructor to communicate, without talking, with a projectionist located behind the screen. A desk placed between the screen and the blackboard is where the student teacher sits. Speakers are located on either side of the desk. Behind the screen are located three 16 mm sound motion picture projectors arranged vertically and set so that each projects an image squarely with the screen (Kersh, 1961).

Each projector holds a motion picture of a class of school students performing various behaviors, most of which are considered to be *classroom management* problems. The student teacher is expected to react to the behavior of the class. His/her reactions are evaluated by the instructor who then signals the projectionist either to continue showing the film currently projected, or to switch to another projector (Kersh, 1961). Changes in class behavior, as demonstrated by the switching of films, provides feedback to the student teacher that the corrective strategy employed was effective. This simulation, while enabling the student teacher to practice some classroom management skills, lacks fidelity overall, since the student teacher is aware that the simulation is contrived and that he/she is interacting with inanimate projection of human beings only. Kersh (1961) maintains that the classroom simulator possesses an essential element, "sufficiently 'realistic' to give the learner the experience with some degree of psychological fidelity" (p. 448). A definition of *psychological fidelity* is not provided. Interaction with individual students within the class is not possible with this simulation.

While the simulator described by Kersh (1961) was a prototype device, a modified version was used experimentally at the Michigan State University at East Lansing in 1965 (Vlcek, 1966). The instructor's control panel is located behind the projection screen in the modified version. Four motion projectors instead of three are used, and they are not mounted vertically. Instead, the projectors are perpendicular to the screen and the images they project reach the screen by being reflected off mirrors aligned to the screen. Photo-electric cells mounted on the mirrors are used to stop the projectors after they show each class sequence (Vlcek, 1966). One projector displays problem sequences, while two others display responses selected on the basis of the student teacher's actions. Vlcek (1966) states that the fourth projector is, "used with a continuous loop of a slow pan around the classroom to aid the subject in associating names from a seating chart with faces of the class members" (p. 88).

There are potential problems with this type of simulation, besides the concerns of fidelity mentioned previously. Vlcek (1966) states that a problem and response sequence is repeated by the simulator, "until the student elicited a desirable response based upon preestablished standards" (p. 88). While it is desirable for student teachers to be able to contend with classroom management problems successfully, it is contentious to imply that there may be only one or two *acceptable* methods that teachers may use. The simulator itself does not decide whether the action of the student teacher is appropriate. The decision is made by the instructor who may not always exercise judgement that is objective. Vlcek (1966) suggests that few methods are considered acceptable and that student teachers may have to try a number of strategies before exhibiting one acceptable to the instructor, "After 'discovering' a correct response, the teacher-trainee then developed a principle which might be applied in solving similar problems" (p. 88). While the approach of *strategy number 1* for *problem A* may work for some teachers, it is fallacious to claim that a particular strategy will be effective for all teacher who use it in situations similar to problem A.

Vlcek (1966) reports that although the simulator was used for over one year, it was discovered that the *discovery learning* approach used requires more time than was available. In an experimental study comparing teaching effectiveness between an experimental group who received instruction via the simulator and a control group that did not, Vlcek (1966) claims that the experimental group, "solved the simulated classroom problems significantly better and more capably" (p. 89). To be sure, Vlcek (1966) adds that the study does not reveal whether the skills learned from the simulator may be transferred positively to an actual classroom. Additional research into the effectiveness of the projection system versus other display systems is also noted as a requirement. Although the classroom simulator was conceived of as answering a need for the rapid instruction of student teachers in a burgeoning educational system, the projected explosive growth did not occur. The end of funding under the Defense Education Act combined with other funding cuts ensured that little development of the classroom simulator would occur subsequently.

Gemini/Tharogem I

It is noted at the outset of this chapter that some teaching machines, most notably those designed by B. F. Skinner, are intended to simulate the most important aspects of the teacher. In this manner, it is contended by Skinner (1954) that individual students may receive instruction from their own personal tutor. While some individuals might contend that Skinner's teaching machines are credible simulations of a teacher, there has been at least one attempt at creating simulations of teachers with higher attribute fidelity.

Hollis (1977) states that in 1923, the Czechoslovakian writer Karel Capek described the creation of mechanical devices that possess some of the attributes and simulate some of the behavior of human beings. These fictitious machines are called *robots*, and while they have been perennial subjects in science fiction motion pictures, actual robots have been created. Although many are devices used to cut material and to assemble products in industrial applications, some are capable of locomotion and they possess on-board computers and sophisticated input peripheral devices to identify objects that they encounter (Hollis, 1977). The advent of small integrated circuits requiring little power has facilitated the design and production of such robots.

By 1985, Artec Systems of Columbia, Maryland, constructed a self-propelled robot capable of limited interaction with students. Called *Gemini*, the robot consists of a plastic housing, approximately four feet (1.2 m) high, containing three computers, rechargeable batteries, a propulsion system consisting of rubber wheels and electric motors, speech recognition circuitry, speech synthesizing circuitry, a 40 character liquid crystal display

(LCD) provision for a keyboard, and touch, optical, infrared and sonic sensors in conjunction with the locomotion system (Artec Systems, 1985). Figure 98 shows the general appearance of Gemini, Artec System's creation of an educational robot.

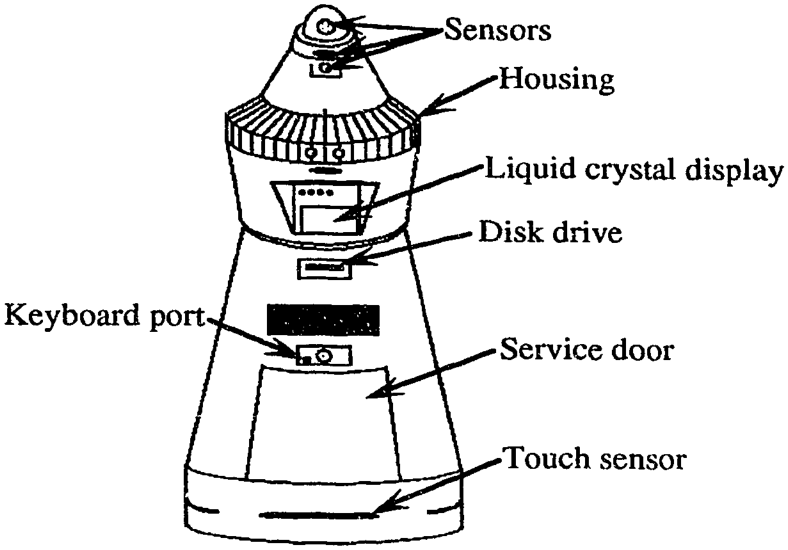


Figure 98. General appearance of Gemini, the educational robot

Two of Gemini's computers control speech recognition and synthesis and locomotion. While voice recognition requires training sessions with the robot, Artec Systems (1985) state that 100 k Bytes of software are resident in the system, so that, "No programming experience is required" (p. 33). User-designed instructional programs may be created for Gemini, using the BASIC language. Gemini is designed to move about a classroom and to interact with students, through voice, instructions on the LCD, and through keyboard commands. Although Gemini is intended to recognize human speech, Artec Systems (1985) note that the unit is capable of recognizing only three different voices.

While Gemini is similar in basic principle to the mechanical turtles designed for the LOGO language (see Chapter VII) there is no indication that Gemini is designed to be compatible with LOGO. Artec Systems (1985) intended marketing copies of Gemini to schools, indicating that, "The GEMINI educational system is ready for you now" (p. 33). It seems that few, if any schools purchased versions of Gemini, since the company is reported as having gone out of business (Personal correspondence with C. DeMund, General Dynamics Corporation, March 9, 1990).

The Electric Boat Division of General Dynamics Corporation acquired the prototype of Gemini and renamed it *Tharogem I* (General Dynamics, 1989). Apart from changing the name printed on the housing, the robot appears to be identical to when it was known as Gemini. Tharogem I was used as a centrepiece of an educational project developed by the Thames Science Center in New London Connecticut (General Dynamics, 1989). Although the program was advertised as a robotics-based instructional system, where the robot simulates the rôle of the teacher, subsequent information reveals that Tharogem I is unique and no other versions are in production (Personal correspondence with C. DeMund, General Dynamics Corporation, March 9, 1990). While the Thames Science Center may use Tharogem I to design experimental instructional systems using robots, no commercial versions are available. The promotion of an instructional device that is not available to educators is similar to the early promotion of teaching machines during the late 1950s (see Chapter VI). While other robots are likely being designed as instructional simulators, their use in schools seems to be limited and is likely to continue to be so until a perceived need for them exists among educators to the extent that the costs of such devices can be justified.

Simulators as expert systems

Jonassen (1988) defines an expert system as a non-human being-based instructional system, "designed to capture and make accessible the operational knowledge of an expert. They are designed for solving finite classes of problems, such as those in trouble-shooting, diagnosis and correction (especially in medicine), and analysis of situations" (p. 300). Wenger (1987) adds that expert systems, since they are attempts at simulating inferred attributes of human beings, are based on current understanding of cognitive processes in human beings and as such, may facilitate the further understanding of human learning and neurological processes. While there may be a tendency among some individuals to accept that the study of expert systems and the larger field of *artificial intelligence* signifies a departure from so-called *traditional* studies of learning and instruction (Bereiter, 1991) there is evidence to show that what is being done is largely re-discovery of existing theories and practices, but new terms and technologies are applied.

It was noted in a previous section about flight simulators, that Gagné (1954) argues that a behavioristic *task analysis* approach results in improved learning when applied to particular simulators used as instructional devices. Although cognitive approaches to instruction are more popular at the present time than behavioristic methods, some seemingly cognitive approaches continue from a behavioristic basis, although terms peculiar to cognitive psychology are used. For example, Means and Gott (1988) contend that while experts who design systems are, "often unaware of the abstract principles, constructed out of experience, that guide his or her problem solving" (pp. 35-36) particular rules are being followed that, once identified, can be quantified and applied to instructional systems. While this analysis appears to be congruent with some cognitive theories of learning and instruction, since consideration is given to inferred abstract or *mental* processes, the final result is a behavioristic approach similar to that proposed by Gagné (1954). Although an expert may contend with problems initially by invoking a particular set of rules and procedures that he/she might not be cognizant of, complex problems sometimes require a departure from simple rule-based problem solving. The sections concerning the problems of designing simulators of complex aircraft to ensure a positive transfer of learning, are examples of where simple rule-based problem solving and instructional strategies fail. Moreover, theoretical limitations caused by limitations to our knowledge of how the human brain functions may also facilitate a continued use of simple and largely behavioristic instructional strategies in expert systems. Psotka, Massey and Mutter (1988) state that when considering learning or *knowledge acquisition*, "The tools provided by AI [artificial intelligence] and cognitive science are stretched to their limits" (p. 15). While these claims may be disputed, there are preëxisting systems that may be considered *expert systems* on the basis of the definitions and discussions presented in this section.

Many simulators described in this chapter and some instructional devices described in previous chapters may be considered expert systems. Although some devices such as the early Link Trainers were not designed from the basis of explicit rules, they function according to rules implicit in the design; rules selected as important by the designer or *expert*. Similarly, some of Pask's early SAKI teaching machines for developing particular keyboard skills (See Chapter VII) are computer-controlled instructional devices not designed as expert systems, but which function as expert systems, nevertheless. Many Skinnerian-type teaching machines are also simulations of particular behavior exhibited by some human beings; behavior considered important in teaching and learning by the expert who designed the simulators. The movement away from motion in aircraft simulators at the end of the Second World War, typifies how expert systems may be altered by considering the recommendations of other experts.

Wenger (1987) contends that some simulations such as STEAMER, described in a previous section, are expert systems that embody principles of artificial intelligence, and which are used for instructional purposes. While such simulations may be designed from the basis of AI and the theories behind expert systems, the use of such simulations is determined, in part, by many of the factors that affect other types of simulators. Positive transfer of learning may not follow, therefore, if such factors are ignored. Chapter IX will discuss some of the factors both limiting and extending the development and use of instructional devices.

Conclusions

Several different types of simulations and simulators have been described in this chapter. While some are designed from the basis of formalized theories of learning and instruction, others are not. Most simulators used for instruction are either designed to simulate aspects of reality, or they attempt to transform abstract ideas into tangible form. The discussion of simulators in this chapter also reveals that most simulators used successfully for instructional purposes are developed to address a perceived need. Continued use and deployment of simulators, however, is in large part dependent upon their efficacy and other factors such as cost. The seeming and measured effectiveness of a simulator is in part determined by the instructional goals it is attempting to attain. Fidelity, dimensionality and the degree to which the simulator is dynamic are all factors that control the instructional efficacy of simulators. While some instructional processes make extensive use of simulators, such as some medical education and much military aviation instruction, other areas of instruction have made either limited or sporadic use of simulators. While it has been shown in this chapter that some simulators are based on appropriate instructional theories, expressed both explicitly and implicitly, factors other than efficacy and instructional design impinge upon simulators in much the same way that the factors impinge upon other instructional devices described in previous chapters. The following chapter examines some of these factors affecting instructional devices and how they appear to interact with other considerations.

Chapter IX

Factors affecting the development and the use of instructional devices

From evidence cited in chapter IV, both the use of teaching aids and the development of new instructional devices were considered legitimate endeavors generally by the end of the 1800s. Some devices, such as the blackboard, gained such widespread use that they transcended the designation *teaching aid*. The blackboard was considered by most teachers to be a *necessary tool* rather than a desirable teaching aid. By the time of the First World War, the increased use of blackboards in many schools and the consequent demand for more blackboards, resulted in a number of manufacturers producing them. Initially, most educational authorities did not stipulate the sizes of blackboards best suited for use in a classroom. Some manufacturers attempted to satisfy the demand for blackboards without considering specific pedagogical requirements for blackboards such as size, colour and composition. The result of this oversight was that blackboards were produced in many different sizes and in many grades of quality. It was possible that if a teacher or a school board was not aware of which type or size of blackboard was best for their intended application, then one of an inferior quality or one that was either too large or too small could be purchased. Instead of functioning as a necessary tool, a blackboard of inappropriate dimension or composition could impede both the efficiency and the effectiveness of the teacher. Concern about the quality and size of blackboards was expressed in remote areas as well as in cosmopolitan centres. In 1903, for example, the Department of Education of the North-West Territories, whose jurisdiction included the areas that now comprise the Canadian provinces of Alberta and Saskatchewan, issued regulations and standards of size and composition for blackboards acceptable for use in its schools (Department of Education of the North-West Territories, 1903). Federal legislation was introduced in the United States several years later (Schmidt, 1930). The effect of such legislation was to guide manufacturers so that they would tend to produce blackboards of acceptable size and quality, thus facilitating the success of the blackboard. It is doubtful that such steps would have been necessary if blackboards were considered to be teaching aids that would alternately be in fashion or not depending upon the prevailing pedagogical theory and method. What occurred to the manufacture of blackboards is significant to note, since it appears that some manufacturers were trying to satisfy a perceived need for blackboards without fully understanding why educators considered a minimum size or a particular composition or color necessary.

It has been shown in previous chapters, that there has been a long tradition of individuals and concerns adapting devices invented for other purposes, to function as either teaching aids or teaching machines. Teaching aids in general were deemed not only useful adjuncts to instruction, but as highly desirable items that should be present in every classroom. Besides the use of and the promotion of teaching aids by educational theorists such as Locke and Montessori, some educational authorities, including ones in areas removed from centres of educational thought and innovation, concurred with such theories and made the use of teaching aids mandatory. As early as 1888, for example, the Board of Education of the North-West Territories required schools in their jurisdiction to possess both blackboards and teaching aids such as maps, reading tablets (a modern equivalent of battledore books) and globes (Board of Education of the North-West Territories, 1888). Two questions arise from this information. First, what are the factors that affect the introduction and the use of instructional devices, and second, why do some instructional devices such as blackboards develop from innovative teaching aids to necessary tools, while other devices pass into obscurity? This chapter will attempt to answer these two questions.

Factors affecting the introduction of instructional devices

General explanations

Some possible reasons for the introduction of instructional devices have been mentioned in previous chapters, notably chapters II through VIII. Although particular devices and circumstances are described and discussed, a common reason why each device was introduced is discernible, *perceived need.* This reason cannot explain the phenomenon without elucidation, since needs in pedagogy usually arise from some perceived deficiency either in instruction or in resultant student performance. Other factors such as a knowledge of available technology, consideration of the economic possibilities and the ramifications of production and use of the device must be considered before an instructional device or an idea for an instructional device can be applied, with any hope of success, to an existing pedagogical system.

While many authors treat innovations in education as a general subject, it is important to bear in mind that this subject is also germane to the introduction and the deployment of instructional devices. Something that is new, or at least unknown to most educators, can be considered an innovation. Although the criteria, models and hierarchies discussed in this chapter may be applied to innovations in general, the primary intent is to apply such criteria, models and hierarchies to instructional devices.

Schlebecker's criteria

Some of the factors affecting the invention of devices were considered by Schlebecker (1977) in respect to technological innovation in general. His four criteria for technological invention, 1) accumulated knowledge, 2) evident need, 3) economic possibility, 4) cultural and social acceptability, have been described and discussed in several chapters previously. While providing a basic explanation of why technological inventions occur, the criteria do not explain fully why certain inventions gain widespread use while others do not. Gaines and Shaw (1986) describe some of the factors that impinge upon the development of innovation.

Gaines' and Shaw's linear development

Gaines and Shaw (1986) consider relevant factors as steps in a supposed linear development of an idea or a technology from invention through common use. They liken this development to typical *learning curves* in human beings. The authors contend that with the development of an innovative technology, like a human being learning an idea or concept, there is gradual development following an initial breakthrough. Growth or development then continues at a rapid rate until most of the information is assimilated. Rapid growth is then followed by a gradual reduction in development as the result of *maturity* of the idea or technology. This entire process is dependent upon previous related developments that have reached maturity (Gaines & Shaw, 1986). Gaines' and Shaw's linear steps attempt to explain why successful innovations and developments require so much time and reliance upon previous development and knowledge. Both Schlebecker's criteria and Gaines' and Shaw's linear steps do little to account for those discernible factors within educational settings that impinge upon the introduction and the development of instructional devices. Consideration of this topic by educators has resulted in more cogent explanations.

Loucks' and Zacchei's ingredients

Loucks and Zacchei (1983) note that in general, most educational institutions and educators are not implementing innovations. Their analysis of the problem suggests that the reason for this failure is that certain crucial criteria are not considered. Rather than organizing these criteria in linear steps, they are presented as four main *ingredients* that must be present during the process of implementation, if the innovation is to gain widespread use. Although Loucks' and Zacchei's ingredients refer to educational innovations in general, the ingredients can be considered in respect of instructional devices specifically.

The four essential ingredients noted by Loucks and Zacchei (1983) are: 1) a well-defined *classroom-friendly* effective innovation; 2) ample and continuous help for teachers from a variety of individuals; 3) a clear direction for administrators; 4) attention to institutionalization. The authors claim that an innovative microcomputer-based writing program known as QUILL, was implemented successfully in some schools by including the four ingredients. It is important to note that while the QUILL program may be successful in particular locations, it has not yet gained widespread use. While local success of the QUILL writing program may be attributable to the four ingredients, each is vague.

It is possible that each ingredient may be interpreted in ways that may result in the failure of the innovation. The description of an effective innovation as *classroom-friendly*, is not clarified further, for example. Who ascertains what is a *classroom-friendly* or an effective innovation? A teacher possibly, a principal, central office personnel, or perhaps a consortium of individuals. Ingredient number three is also ambiguous. What is meant by a *clear direction*, and who provides it to administrators? One may assume that either the designer of the innovation, its promoter, or some unspecified individual or group provides this *clear direction*. Although Loucks and Zacchei (1983) attempt to provide criteria to help ensure that important factors relevant to the successful implementation of an innovation are considered, they fail to define the criteria so that they are not vague.

Bishop's logical steps

Bishop (1986) proposes a six-step hierarchical process to explain generally how educational innovations may become commonplace. Although Bishop (1986) does not mention instructional devices such as teaching machines and teaching aids specifically, such apparatus are considered to be subsumed under the topic innovations. His hierarchy can, therefore, be applied both to instructional devices as well as to innovative programs. Step one begins with the recognition of a problem, dissatisfaction or need. Consideration of possible solutions comprises step two. In step three, a particular solution (some sort of innovation) is selected as being most appropriate. Trial and evaluation is the fourth step, followed by wider implementation if the trials are deemed successful. The final step is the universal implementation or institutionalization of the innovation.

In explaining these six steps or phases, Bishop (1986) states that it is necessary to identify the *real* nature of the problem, which in some instances may not lie within education at all. What Bishop (1986) does not appear to consider, is the possibility of a genuine problem or concern in education being exaggerated or misrepresented by concerns who wish to have a particular innovation or instructional device deployed for reasons other than those of solving an actual pedagogical problem. Most teachers admit, for example, that their teaching methods can be improved. Instructional devices that are promoted as *time-savers* for the teacher, or devices that are claimed to embody pedagogical methods that will improve student achievement markedly, purport to address perennial concerns of most teachers. Many such devices are produced by manufacturers solely for profit, with little or no regard for the improvement of pedagogy (Bennett, 1925; Skinner, 1965). The profit motive can be a major factor motivating manufacturers to produce instructional devices. A local business concern in Edmonton, for example, which manufactures varieties of bead frame teaching aids and sells them throughout

Canada and the United States, obtained revenue of $1.5 million during 1989 (Chalmers, 1990).

Bishop (1986) also adds provisos concerning the selection of innovations. He states that, "just because something is new or different it need not necessarily be better than the system it is transplanting" (p. 5). Although this caveat suggests caution when selecting an innovation, Bishop's steps do not appear to contend with many of the intervening factors that can affect the deployment of an instructional device. For example, a *band-wagon* effect, originating either within or without the educational setting may either spur the deployment of an innovation, or it may hasten its abandonment. In such cases, the actual merit of the device is likely not to be the primary concern.

To better explain the various dynamic factors affecting the development, implementation and ultimate fate of instructional devices, a new model has been created that incorporates elements from existing models.

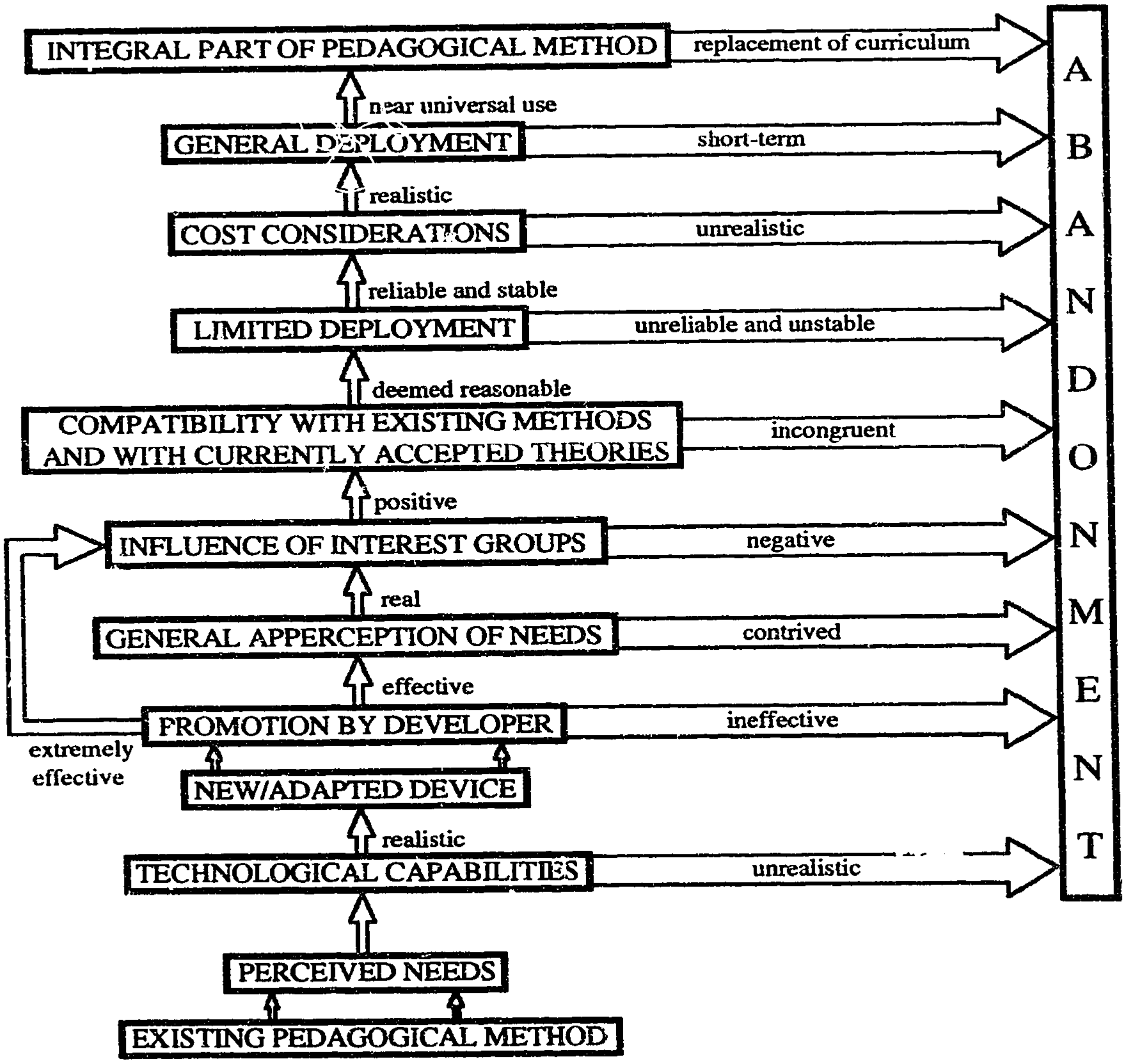


Figure 99. Development and implementation model

While the development and implementation model may resemble some of the linear models discussed previously, it is important to note that movement through this new model is not entirely linear. While the general direction of movement is in one direction, there are particular stages that may be bypassed, and each stage of the model contains a branch leading to abandonment of the innovation if particular criteria and/or circumstances are not met. The rationale for constructing a new model based upon prior models and explanations, is to both incorporate appropriate elements from them as well as to minimize the repetition or the re-invention of those errors and oversights that are discernible in earlier work.

Development and implementation model

Description

To use the model, it is necessary to start at the bottom with an idea for an instructional device and then proceed upwards. A general explanation of the model will be provided as well as applications of the model to the development of particular instructional devices, to show how the model may function in practice.

General explanation

Initial stages

Beginning with a perceived need, either from a pedagogical basis or from some other motive, an individual, group or corporation considers technological possibilities for a device that can satisfy a perceived need. If the designers envisage apparatus that is not possible to construct, given the available technology, then the idea is abandoned, or at least shelved until technological developments permit further development of the idea. If the technology exists to transform the idea into reality, then a new device is produced. It is important to note, especially where individual designers are concerned, that the execution of the device may be constrained by limits of the designer's awareness of available technology. In such cases, a new device may be created that is later abandoned when more appropriate technology is applied, rendering the old device obsolete.

Once a prototype is produced, the developer has to make educators aware of the device and the reasons why it should be used. If only a small number of people learn of the device, then it is likely to be abandoned because of a lack of sufficient interest. If the device receives widespread notice, then the rationale and the justification for its use must be recognized by its intended users. A developer may, for example, create a device simply because a potential profit is perceived if it is marketed in particular educational settings. In such cases it is possible that the device will be rejected and abandoned by its intended users because they will likely not perceive the device as truly addressing a genuine need within the existing pedagogical system. Notable exceptions to this step are many of the devices produced for use in the home and in other unstructured educational settings such as day care centres. In such cases, the purchasers of the devices usually cannot or do not consider whether or not the device is effective pedagogically. This step of the model can be circumvented in some instances. If the developers of the device are able to promote it successfully to the interest groups that influence and control the selected pedagogical system, then the device may be introduced without considering the individuals who have to incorporate its use into the curriculum (see Chapter VII, especially sections describing factors affecting deployment). Havelock and Huberman (1977) also recognize this possibility and caution that innovations forced in this manner, "tend to lurch from crisis to crisis and to end up as large -scale 'pilot projects' with little prospect of being generalized as long as they are propped up by special resources and unusual administrative support" (p. 78). If the general consensus of the interest groups is that the device is inadequate, however, then it is usually abandoned. If the interest groups consider the device to be appropriate for whatever reason, then it has to be integrated with the pedagogical methods currently in use.

Bandwagon effect

One factor that may lead an interest group to believe that a particular instructional device or a class of instructional devices is appropriate for use, is the so-called *bandwagon effect.* This condition is the result of an assumption that an apparent trend of increasing interest in a device, or a class of devices, is a reflection of their merits and practical usefulness; if a large number of individuals are interested in something, it must be good. This assumption may also obscure objectivity, so a device or a class of devices may be deployed without considering other factors. A possible result of such action may be that design flaws or flaws of manufacture will affect a large number of people rather than just a few individuals if deployment was limited initially. Another result might be the abandonment of the device because its purpose is not understood by the individuals who are responsible for its deployment or who must supervise its use.

What these statements imply, is that the sample which indicates an increasing interest in the device may not represent the level of interest of those individuals who deploy the device or supervise its use. Glaser (1960) provides one example of how the bandwagon effect can lead to erroneous conclusions. He concludes that an apparent high interest in teaching machines is indeed a reflection of their effectiveness, since they are based largely on scientific findings of "learning-theory-oriented psychologists" (p. 29). Glaser (1960) contends further that teaching machines should be deployed in classrooms as soon as possible so that instruction may be improved, "let us try to apply effectively as much as we know; it might be enough to make a difference" (p. 31). Glaser's conclusions seem to have been influenced by the bandwagon effect. As noted in Chapter VI, while there was an apparently rapid increase shown in teaching machines by individuals writing articles, this trend was soon followed by an equally rapid decline in interest. At the same time, there was no indication that the teachers who were expected to use teaching machines shared the level of enthusiasm for teaching machines exhibited by authors of articles. To make predictions based on evidence that does not show a causal relationship clearly, therefore, suggests that the predictions are the result of the bandwagon effect. As well, by contending that short-term trends indicate an acceptance of an instructional device, one is likely to be a victim of the bandwagon effect.

While it is mentioned previously that Glaser seems to have been a victim of the bandwagon effect, Glaser himself came to realize the some of the problems that it can cause. Glaser (1965) states,

> I was greatly concerned that the uncritical rapid acceptance and too-ready use of programed instruction would accomplish two things: that high expectations coupled with awkward usage would result in disappointing outcomes and that the rush toward immediate practicality would pull the field away from its loose ties with the scientific study of behavior. (p. vii)

Although Glaser (1965) qualifies his position by noting that actual developments were different from predicted extremes, the bandwagon effect did hinder rather than help the deployment of teaching machines and programmed instruction. As noted in Chapter VII, the bandwagon effect has also affected the development and deployment of particular computer-controlled instructional devices. It is likely, therefore, that the bandwagon effect is a phenomenon that may affect any instructional device introduced.

Compatibility

If an instructional device requires a radical change to the existing pedagogical method or system, a drastic change of the teacher's role and function for example, then the individuals who have to deploy the device may not approve of it. Abandonment of the device is the ultimate result of such rejection or reluctance. The analysis and discussion of B. F. Skinner's teaching machines in Chapter VI, is an example of how incompatibility of an instructional device with existing methods can contribute to its abandonment.

If the instructional device meets with the approval of those who must make use of it, usually the individual classroom teacher, then the device is likely to be placed in limited use to ascertain its strengths and weaknesses. Poor performance or poor reliability usually result in the device being abandoned. Evidence to show that the device does what it is intended to do and that its performance is reliable, may result in its consideration for general use.

Cost considerations

At this juncture, cost becomes an important consideration, given that large numbers of the device are likely to be required for general use. If the unit cost or the total cost is considered too high either by educational personnel, or by interest groups such as the parents or taxpayers, then the device will likely be abandoned. If the cost is considered reasonable within the funding available, then the device will be placed in general use. There is a confounding factor that may intervene at this point. The apparent success of the instructional device may encourage other concerns to market a similar device. In some cases, the motive of these concerns is only to realize the maximum profit through any means, including misrepresenting the product. An example of this occurrence are some of the teaching machines sold, intended to teach control of enuresis (see Chapter V). A possible result of such unscrupulous marketing techniques is the abandonment of the device because individuals will not buy any model, even though the device is effective, for fear of being cheated.

Other cost-related variables include laws and legislation that permit manufacturers and publishers to gouge buyers of their products. Prototypes or test versions may be sold at reduced rates to promote the product and to subject it to field testing. When production begins, however, some concerns employ means provided to them by legislation, to extract money from their customers for protracted periods. An example of this phenomenon is a manufacturer of an instructional device that does not permit the device to be purchased outright, but to be leased on a yearly basis. Not only can the rate charged per year be raised, but the contract may also stipulate that any maintenance and repair work required must be carried out by the lessor, at his rates. A similar situation can exist with software and courseware for instructional hardware that might already be owned by a school or by some other educational body. Manufacturers may stipulate that a copy of the courseware must be obtained for each machine or, if a site licence is requested, an extremely high rate is charged. While it may be argued that the first goal of business is to make a profit, an intemperate desire to gain the maximum profit may result in the general abandonment of an instructional device, since the intended buyers may consider more traditional methods of instruction to be less expensive. A possible outcome of this sort of action, is that any pedagogical merits a device might have will no longer be the first consideration. This is especially true with respect to multi-purpose devices such as microcomputers which can be used for purposes other than instruction.

General deployment and integration

When an instructional device is not integrated into the existing pedagogical method because of economic necessity, then its ultimate fate depends upon what happens to it in general deployment. If, after a short-term of use, it is found that the need for the device is no longer present or valid, then the device is usually abandoned. If the device continues to be used for a protracted period, then it is likely to be integrated into the pedagogical method. At this point, the instructional device will continue to be used until a technological improvement makes it obsolete, or until the need for the device ceases.

Examples applied to the model

Several examples of instructional devices will be applied to the development and implementation model to demonstrate its applicability. The first device to be considered will be an ancient teaching machine, the quintain (see Chapter II for description and discussion).

Quintain

There was a method of teaching soldiers how to attack with their swords before the quintain was devised. From what Vegetius states, however, there was a problem in ensuring that recruits thrust rather than slashed with their swords. The paucity of Centurions and other training supervisors, combined with high mortality rates on the battle field as the result of poor sword technique, would indicate that a more effective teaching method might improve the efficiency as well as the life-span of the individual soldier. While one solution to poor sword technique is to provide one trainer for each recruit, the method is impractical because of the large number of personnel required as well as the expense. An innovation that would solve the problem without great expense and without increased personnel would be ideal. There was a perceived need for an improvement to the existing pedagogical method, therefore. Technological possibilities were limited at that time, but it was possible to construct a quintain using existing technology and materials. Although the particular developer of the quintain is not known, we do know that its use was promoted effectively because of its ultimate widespread use. The need for the quintain appears to have been considered real generally, given the evidence of its extensive use and the account of Vegetius who notes problems with existing training methods. The influence of interest groups was likely positive, since the use of the quintain in training probably resulted in fewer casualties as the result of mistakes in swordsmanship. In addition, the quintain does not appear to have had to compete with other devices or innovative methods that claimed to improve sword training. The quintain was compatible with existing methods, since it could replace or supplement the palus. No extensive change to the method of soldier training was required, therefore. Cost considerations do not appear to have been a problem, given that quintains were usually of a simple design and were fabricated from common and inexpensive materials. Limited deployment of the quintain within particular Roman armies resulted in comparisons being made of battle effectiveness between units that trained with the quintain and with units that trained without them. The demonstrated effectiveness of the quintain and its reasonable cost probably contributed to its general deployment. It seems that the near universal use of the quintain resulted in its incorporation into the pedagogical method, thus creating a new pedagogical method. Not only did the use of the quintain supersede previous methods for teaching proper attack technique with a sword, but the quintain survived as a teaching machine for more than one millennium, further indication that it became an integral component of a new pedagogical method. This contention is supported further by the fact that the quintain continued to be used as a teaching machine for knights well after the disappearance of the Roman foot soldier.

Blackboard

The blackboard is a contemporary example of an innovative instructional device that can be analyzed by the development and implementation model. Recalling the description of its development and deployment presented in Chapter IV, the blackboard or its equivalent is now found in almost every classroom at present, and is therefore considered a *necessary tool*. An innovative idea, the blackboard seems to have arisen from a perceived need in an existing method of pedagogy. Technological possibilities included both writing on walls and the use of small slates initially. The impractical nature of writing on walls directly, probably lead to the abandonment of that innovation. The principle of presenting information in such a manner, however, could be realized with blackboards only when technological developments permitted the production of large writing surfaces. Other factors in the development and implementation model were contended with successfully, and the merits of the blackboard as a teaching aid were recognized and accepted generally. The blackboard, or analogous devices intended for use in special environments such as overhead projectors for use in large lecture theatres, are no longer considered novel innovations or teaching aids for limited use. The blackboard or its equivalent is an essential part of most pedagogical methods in use at present.

Gerbert's teaching machine

There are many more examples of both teaching aids and teaching machines that have failed to gain widespread use. One example is the teaching machine devised by Gerbert (Pope Sylvester II) for showing the configuration and the location of particular constellations (see Chapter III). While the device satisfied a need perceived by Gerbert and by some of his contemporaries as well, it was primarily the influence of interest groups that caused his teaching machine to be abandoned. It can be contended that the individuals who condemned Gerbert's teaching machines, from the basis that they were inspired by the devil, were probably ignorant of the pedagogical merits of the apparatus. This consideration probably did not mollify many educators' fears about possible consequences if they continued to use Gerbert's devices, given the power that this interest group (fundamental elements of the church) possessed.

Touch Tutor teaching machine

A recent example of instructional devices that failed is one of the many teaching machines that were introduced during the 1950s and the 1960s. The majority of these are based on the behavioristic theories of B. F. Skinner, who also introduced teaching machines of his own. Skinner's endeavors actually represent two discrete innovations introduced at once. A new pedagogical theory, Skinnerian behaviorism, plus an innovative way of providing instruction. Both the theory and the machine, therefore, are subject to the steps listed in the development and implementation model. Teaching machines based on Skinnerian theory have greater difficulty of attaining success than instructional devices designed to be compatible with existing pedagogical methods. If Skinner's pedagogical method had happened to gain widespread use first, then each teaching machine would be considered on its own, not in combination with a new theory of instruction. Given that most of these teaching machines were introduced before the embodied pedagogical method (Skinnerian behaviorism) had gained general deployment, it is understandable why few varieties of this type of teaching machine were considered either useful or necessary. The Touch Tutor teaching machine being one such example.

Devised by Farrall Instruments of Grand Island, Nebraska in the early 1960s, and based on the principles of Skinnerian behaviorism, the Touch Tutor was intended to be a teaching machine that could be used in most educational settings. Apart from four prototypes, the machine was never placed in production. In explaining why production never began, the president of the company, W. R. Farrall, states, "the people in the field [educators] could not understand its value" (personal communication, September 23, 1988). Farrall's explanation is partially correct. The actual teaching machine may have been designed carefully and well-constructed, and it may have been appropriate for its intended purpose as a Skinnerian-type teaching machine. These considerations seem to have been of little concern to most educators. Likely of greater concern was the value of the underlying pedagogical theory, Skinnerian behaviorism. The failure of most educators to accept Skinner's theories of learning and instruction meant that teaching machines embodying these theories would not be used, regardless of other factors impinging upon the machines.

Devices adapted for instruction

To this point, the examples applied to the implementation and development model consist of devices designed initially for educational purposes. Several devices are described in Chapters IV and V, that were invented for purposes other than education, and which have been adapted for use as instructional devices. The successes and the failures of such devices adapted for instructional use may also be explained by means of the implementation and development model. One example is the use of motion picture films in schools.

While it is generally accepted that the first commercially viable motion picture films were produced by Thomas Edison by the early 1890s, such films were intended to be a form of entertainment rather than a method of instruction. While the use of motion pictures in schools was promoted by many individuals and groups, including the improbable predictions of Edison, the actual speed of deployment was extremely slow. This phenomenon frustrated many proponents of this teaching aid, to the extent that some tried to engender a bandwagon effect, thus encouraging others to ignore factors such as cost, compatibility and pedagogical efficacy. For example, Aughinbaugh (1930), complains that most schools continue to be reluctant to use motion pictures in their classrooms, in spite of the commercial success of that technology,

> the world has accepted and welcomed this innovation ... With this evolution going on, the schools cannot afford to tarry long. Even now they have lost much of their one-time prestige. When the boy or girl learns something more of geography, history, biology, physics, and so on, from the theater around the corner than he does from his school, the latter is bound to suffer in his estimation. (p. 54)

While Aughinbaugh's (1930) claim, that a student may learn more by watching a film than from traditional teaching methods, can be contested, there are studies from that period which indicate that learning can occur through watching particular motion pictures (Peterson & Thurstone, 1932). Instead of citing such evidence, Aughinbaugh chose to encourage a more rapid deployment of the innovation through the bandwagon effect. Aughinbaugh (1930) states, "Institutions which fail to keep abreast of the times are swiftly passed. Like China, we cannot worship the past without endangering our position in the present" (p. 54). In spite of Aughinbaugh's spirited promotion of motion pictures for instructional use, he does not address other factors that have retarded the deployment of motion pictures in schools; factors that are encountered in the development and implementation model. As noted in Chapter V, technological limitations and equipment design is one such factor that has hindered the deployment of this teaching aid.

Computers adapted for use as instructional devices

Some of the problems encountered with using computers in schools as instructional devices, bear similarity with some of the factors which have affected the deployment of motion pictures in schools. Manufacturers of computers have designed their machines to function with distinctive operating systems that are not usually compatible with the operating systems of machines produced by other manufacturers. The construction of particular machines (hardware architecture) as well as the means that a user can interact with the machine (user interface) are not standard within the industry. Computer programs (software or courseware) must be configured to conform to the operating characteristics and the constraints of each type of machine, therefore. This attribute forces schools either to select one particular type of machine, or to purchase a variety of machines so that most appropriate software for each can be used. Manufacturer support for particular models of computer can be remarkably short-lived. A school equipped with the latest model in a given year, is likely to discover that it is obsolete within three years. While obsolete machines can continue to be used, they are usually unable to run the most up-to-date software without costly upgrades, if the machines can be upgraded at all. Older machines, as well, usually cannot take advantage of improvements to the hardware architecture or to the user interface. Such improvements include specialized peripheral devices such as touch-sensitive screens as well as enhanced memory and processing capabilities.

It is noted in Chapter VIII, that these factors come to bear even when educators themselves design a computer-controlled instructional system. While IBM's 1500 system was used successfully by many institutions for instructional purposes, financial and technological considerations resulted in the system disappearing by 1980. Similarly, the ICON computer devised in Ontario, failed to gain widespread use because of hardware limitations and the inability of the equipment to use software and courseware designed for other microcomputers. Again, factors within the development and implementation model were not considered by the designers of the ICON, or by the governmental authorities who perceived the ICON to be the solution for computers in schools.

Hardware factors comprise only part of the problem of deployment. Appropriate software that is well-designed and tested, and which will function in a classroom the way it is intended to, appears to be in short supply. Much software and courseware relies heavily on the input of the teacher, who is usually not provided with additional time to provide this input. An assumption inherent with such software and courseware is that the individual teacher has both the ability and the inclination to provide the necessary input. This assumption is at variance with a perception held by many educators and lay people, noted by Hunka (1977) who expect computers and software to begin comprehensive instruction to students once the hardware is set up and the courseware installed.

The cost of both hardware and software and/or courseware is another major factor. While the cost of an individual computer continues to drop, it is still a great expense for schools to outfit an entire classroom with sufficient computers for each pupil. A one-time expenditure will not suffice, since these machines will require maintenance, repair, upgrading and eventual replacement. The cost of software and courseware is significant, especially considering the current status of many copyright laws, especially those of Canada, that makes no provision for schools with their usual limited and modest budgets. As with the deployment of the motion picture in schools, factors other than pedagogical efficacy seem to be the major determiners of whether or not computers will gain general deployment in schools as instructional devices.

Necessity for instructional devices

It is noted in previous sections that most instructional devices fail to become part of a prevalent pedagogical system or method, yet the perceived need for instructional devices appears to be perennial. Why should any new educational device either be developed or considered for use, in view of the dismal success rate of most devices? Although most instructional devices ultimately fail to gain widespread use, there have been particular examples, most notably the blackboard and military use of flight simulators, that have resulted in a notable improvement in the effectiveness of teaching. Where they have succeeded, instructional devices have altered the fundamental pedagogical system, usually to its improvement. It is important to recall from Chapter IV, that the introduction and the use of instructional devices has gradually been increasing since the seventeenth century A.D. Concurrent with the success of particular instructional devices was the general acceptance of the theory of learning which contends that abstract concepts can be learned more effectively if they are related to some concrete representation. While it has been argued that this idea is not new (see Chapter III), evidence is cited in Chapter IV to show that by the twentieth century, many educators, either explicitly or implicitly, accept this theory of learning. The mandatory use of instructional devices in the North-West Territories by the late 1880s, supports this contention.

Evaluation of the model and its uses

Evaluation

From an initial consideration of the development and implementation model, it might seem that it is practically impossible for an instructional device to reach the stage where it becomes a necessary tool in a new pedagogical method. In consequence, one might be inclined to state that this model is biased against the success of instructional devices, considering that there have been a number of them that have become integral parts of pedagogical methods. The findings of other educators, however, support the contention that few instructional devices as well as innovations in general, ever gain widespread use. While Bishop (1986) refers to innovations in general and not to instructional devices specifically, he claims that up to 70% of educational innovations ultimately fail to gain widespread use. Havelock and Huberman (1977) also claim that most innovations fail, but they do not estimate an actual percentage. They contend that the main reason for the failure of innovations is that their implementation usually entails changing an existing system, and since most systems tend to resist change, it follows that the innovation will fail to be adopted unless it can be incorporated into the system. A similar view is advanced by McLaughlin (1978) who states that the reason most educational innovations fail is because they do not follow any particular model of implementation. In consequence, the operation of the innovation as well as its purpose are not understood by those individuals, usually teachers, who must implement it. McLaughlin (1978) notes further that innovations are rarely implemented without the understanding and the active support of the implementers and the users of the innovation. This view is also shared by Wirt (1978) who advocates a strategy of *mutual adaptation*, where the needs of both the developer and the user of the innovation are considered. Without following a recognizable model of implementation, therefore, it is possible that factors significant to the success of an innovation, such as support from the intended users, can be overlooked with failure of the innovation as a result. Further support is provided by Elmore (1978), who states,

> What grates most on the sensibilities of teachers, social workers, employment counselors, and the like is the tacit assumption in most policy directives that they are incapable of making independent judgements and decisions — that their behavior must be programmed by someone else. It is difficult for persons who see themselves as competent, self-sufficient adults to be highly committed to politics that place them in the role of passive executor of someone else's will. (p. 207)

From the examples that have been applied to the development and implementation model, one may conclude that considerable time is usually required before a new instructional device gains widespread use. Although it might appear that this aspect of the development and implementation model is in error, others have noted that the deployment of instructional devices is slow, even though the merits of the particular devices may seem to be obvious (Aughinbaugh 1930). Evidence has been cited in previous chapters to show that the forced deployment of an instructional device will likely lead to its abandonment rather than to its general deployment.

Given these examples, as well as the *prima facie* evidence of many failed instructional devices, the development and implementation model probably does not present a biased view of the factors that impinge upon the development and the implementation of instructional devices.

Uses of the model

While examples have been provided to show how the development and implementation model can be used as a diagnostic tool to analyze both successful and unsuccessful instructional devices, the model can be used for other purposes as well. Knowledge of the model may help innovators and developers of instructional devices to be aware of some of the major factors that affect both the development of an instructional device and its implementation. Recognizing and considering these factors may result in developers, innovators, manufacturers and users of instructional devices being able to work more closely together to identify the needs for a particular device as well as to ascertain whether or not the device is viable for education in general or only for specific educational applications. Also, by being aware of the importance of pedagogical method and the underlying theory, manufacturers may realize that schools are not businesses motivated by productivity and profits. By being aware of such factors, it is possible that developmental, manufacturing and business concerns will gain a better understanding of what educators tend to consider when they evaluate an instructional device. Similarly, if educators are also aware of the factors in the development and implementation model, then it is possible that such educators will avoid being victims of the bandwagon effect and will also realize that the deployment of instructional devices is usually a protracted process that will be harmed if it is forced.

Concluding remarks

It may be discerned, by considering the examples of instructional devices described and discussed in previous chapters, that the course of most instructional devices follows a cycle, beginning with invention/adaptation, proceeding to implementation and ending with abandonment. While this work has concentrated primarily on older devices the cycle or pattern also appears to be valid for more recent instructional devices. Chapter VII described the development and deployment of computers as teaching machines. While some educators and scholars continue to maintain that computers used in this way will change the methods of education, the failure of this technology to create such change universally in the course of over 25 years, has resulted in some scholars and educators concluding that this goal will never be attained by computers and that their future as teaching machines is doubtful. An example of this view is the article by Cartwright (1991) who also suggests that the course of most instructional devices is cyclical in nature. Cartwright, like Skinner before him, is unable to explain fully the reasons why their respective instructional devices failed to become an integral part of prevalent pedagogical methods. While a single reason does not consider all of the factors affecting an instructional device, it is important to consider the model shown in Figure 99. If the perceived need for the device is not shared by the individuals for whom the device is intended, then it appears unlikely that much effort will be made by such individuals to preserve and increase the deployment of the device.

From considering the factors mentioned in this chapter and in previous chapters of this work, it seems that the cyclical pattern associated with the deployment of instructional devices is more appropriately thought of as an epicycle when considering the context of education as a whole. It appears that in spite of what has happened with instructional devices introduced in the past, many educators, politicians and other educational stakeholders do not learn from what has gone before them, with the result that subsequent instructional devices that arise follow the same cyclical pattern as many devices introduced in the past. This view is shared by Cartwright (1991) who states that in spite of the failure to achieve widespread use of computers as teaching machines, many educators seem anxious to jump on another bandwagon supporting some other new *revolutionary* technology, "Just around the bend on this new electronic highway lies the incredible world of artificial intelligence, virtual reality, and cyberspace. Does anyone feel another revolution coming on?" (p. 155). Cartwright's observations appear to possess some validity, since there are some articles that suggest that in future, teaching in schools will be changed significantly because of the deployment of artificial intelligence and virtual reality (Ferrington & Loge, 1992). While enthusiasm for these technologies builds within in some quarters in education, it would be wise to recall the cost and difficulty already experienced by military organizations attempting to use elements of virtual reality (see chapter VIII). Further evidence is supplied by Levin (1989) in his description of the difficulties in simulating a dynamic model of a typical protein surrounded by water molecules. He states that, "About one hour of Cray XMP computer time is required to simulate 100 picoseconds of behavior" (p. 1456). This quote should be compared with the letter written by a teacher in Los Angeles, California. Responding to an article suggesting that educators were slow to take advantage of modern technology, since most schools continue to use Apple II-type computers rather than faster newer models, Penso (1992) states, "Perhaps he's unaware of how educators struggle to transform outmoded materials into productive experiences for children .... The fault ... lies not with the educators who always struggle to make do with less but with the legislators who fail to fund education and the public that fails to demand quality instruction" (p. 16).

Besides the factors of cost and technological capabilities which do appear to be considered by some individuals, other factors appear not to be considered at all. Recalling the development and implementation model shown in Figure 99, little thought seems to be given at present as to whether artificial intelligence and virtual reality are congruent with prevalent pedagogical theories as well as with prevalent socio-political views. These sentiments are shared by Forester and Morrison (1990) who question both the efficacy and the social appropriateness of expert systems and artificial intelligence. Forester and Morrison (1990) also reiterate a concern discovered with many instructional devices used in the past, they cannot be relied upon as though they do not fail or have limitations. Moreover, Forester and Morrison (1990) state, "this situation is only exacerbated by users [and/or educators] who place blind faith in their technology, developers who abbreviate the design and engineering process, and consultants who are unrealistic in representing the state and accuracy of the knowledge they possess" (p. 86).

If the apparent trend towards trying to deploy artificial intelligence and virtual reality continues in the manner it has, without the consideration of other factors that may result in the postponement of the deployment, then it seems likely that these technologies as teaching machines will be as successful as the teaching machines developed by Pressey, Skinner and others in the past. It seems that until educators and legislators begin to consider what has occurred in the past and learn to build on both prior successes and mistakes, instructional devices will continue to be deployed and abandoned in a cyclical nature and constructive progress in education will continue to be a slow and haphazard process.

BIBLIOGRAPHY

Abrahamson, S., Denson, J. S., & Wolf, R. M. (1969). Effectiveness of a simulator in training anesthesiology residents. *Journal of Medical Education, 44* 517-518.

Adam, Rouilly Ltd. (1988). Instruction aid. *Midwife Health Visitor & Community Nurse, 24*, 384.

Advisory Group for Aerospace Research & Development. (1986). *AGARD conference proceedings No. 408: Flight simulation*. Cambridge, U. K.: North Atlantic Treaty Organization.

Agamirzian, I. (1991). Computing in the U.S.S.R. *Byte, 16*(4) 120-129.

Alberta Department of Education. (1912-14, 1948). *Annual reports*. Edmonton: Author.

Alberta Education. (1983). *Computers in schools: The report of the Minister's task force on computers in schools*. Edmonton: Author.

Alberta Education Curriculum Support Branch. (1987). *A strategic plan for microcomputers in schools*. Edmonton: Author.

Alessi, S. M., & Trollip, S. R. (1985). *Computer-based instruction: Methods and development*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Alessi, S. M. (1988). Fidelity in the design of instructional simulations. *Journal of Computer-Based Instruction, 15*(2) 40-47.

Allion, H. L. (1958). Audio-visual aids for self instruction. *Audio-Visual Instruction, 3*, 14-15.

Alpert, D., & Bitzer, D. L. (1970). Advances in computer-based education. *Science, 167*, 1582-1590.

Americana Interstate Corporation. (1966). The Readamatic pacer: advertisement. *Audiovisual Instruction, 11*, 495.

Anderson, C. (1962). *Technology in American education: 1650-1900*. Washington, DC: U.S. Department of Health, Education, and Welfare.

Andriessen, J. J., & Kroon, D. J. (1980). Individualized learning by videodisc. *Educational Technology, 20*(3) 21-26.

Angell, G. W., & Troyer, M. E. (1948). A new self-scoring test device for improving instruction. *School and Society, 67*(1727) 84-85.

Aristotle. *Rhetorica*. (annotated by W. D. Ross, 1959). Oxford: Oxford University Press.

Arnett, E., Trout, H., & Clarke, S. C. T. (1962). *Programmed instruction: An outline of developments in teaching machines, programmed notebooks, and scrambled textbooks*. Edmonton: Alberta Teachers' Association.

Arnspiger, V. C. (1933). *Measuring the effectiveness of sound pictures as teaching aids*. New York, NY: Teachers College of Columbia University.

Artec Systems. (1985). Experience the excitement of robotics: Advertisement. *Technical Horizons in Education Journal, 13*(1) 33.

Atkinson, R. C. (1968). Computerized instruction and the learning process. *American Psychologist, 23*, 225-239.

Atkinson, R. C., & Wilson, H. A. (1969). Computer-assisted instruction. In R. C Atkinson & H. A. Wilson (Eds.) *Computer-assisted instruction: A book of readings*. New York, NY: Academic Press.

Audio Visual Research. (1962). Why Reading Rateometer has led all reading aids since 1953: advertisement. *Audiovisual Instruction, 7*, 185.

Augarten, S. (1984). *Bit by bit: An illustrated history of computers*. New York, NY: Ticknor & Fields.

Aughinbaugh, B. A. (1930). The motion picture and the school. *School Board Journal, 81*(3) 54, 100.

Aughinbaugh, B. A. (1934). The motion picture as a basic teaching tool. *The National Elementary Principal Thirteenth Yearbook: Aids to Teaching in the Elementary School, 13*(5) 338-343..

Austwick, K., (Ed.). (1964). *Teaching machines and programming*. New York, NY: The Macmillan Company.

Ausubel, D. P. (1962). Learning by discovery. *Educational Leadership, 20*, 113-117.

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning: An introduction to school learning*. New York, NY: Grune & Stratton.

Baggaley, J., Jamieson, G. H., & Marchant, H. (Eds.). (1975). *Aspects of educational technology, volume VIII: Communication and learning.* London: Sir Isaac Pitman and Sons Ltd.

Bandura, A. (1965). Influence of models' reinforcement contingencies on the acquisition of imitative responses. *Journal of Personality and Social Psychology, 1*(6) 589-595.

Bannatyne, A. (1966). A research evaluating teaching machines for junior high school use. *Programmed Learning, 3,* 21-29.

Bedini, S. A. (1964a). *Early American scientific instruments and their makers.* Washington DC: Smithsonian Institution.

Bedini, S. A. (1964b). The role of automata in the history of technology. *Technology and Culture, 5*(1) 24-42.

Bedini, S. A., & Maddison, F. R. (1966). Mechanical universe: The astrarium of Giovanni de Dondi. *Transactions of the American Philosophical Society,* new series *56,* part 5.

Beeler, S. (1933). Electrical teaching device. *Industrial Education Magazine, 35*(3) 50.

Bell & Howell introduces "Language Master". (1964). *Teaching Aids News, 4*(6) 14-16.

Benjamin, L. T., Jr. (1988). A history of teaching machines. *American Psychologist, 43,* 703-712.

Bennett, H. E. (1925). *School efficiency: A manual of modern school management.* Boston, MA: Ginn and Company.

Bereiter, C. (1991). Implications of connectionism for thinking about rules. *Educational Researcher, 20*(3) 10-16.

Best, J. B. (1989). *Cognitive psychology.* St. Paul, MN: West Publishing Company.

Bishop, C. K., & Regan, J. J. (1962). Programed instruction in the armed forces – an overview. In S. Margulies & L. Eigen (Eds.) *Applied programed instruction.* New York, NY: John Wiley and Sons, Inc.

Bishop, G. (1986). *Innovation in education.* London: Macmillan Publishers.

Bitter, G. G., & Camuse, R. A. (1988). *Using a microcomputer in the classroom.* Englewood Cliffs, NJ: Prentice Hall.

Bitzer, D. L. (1976). The wide world of computer-based education. *Advcnces in Computers, 15*, 239-283.

Bitzer, D. L., Braunfeld, P. G., & Lichtenberger, W. W. (1961). PLATO: An automatic teaching device. *IRE Transactions on Education, E-4*(4) 157-161.

Bitzer, D. L., Braunfeld, P. G., & Lichtenberger, W. W. (1962). PLATO II: A multiple-student, computer-controlled, automatic teaching device. In J. E. Coulson (Ed.) *Programmed learning and computer-based instruction: Proceedings of the conference on application of digital computers to automated instruction.* New York, NY: John Wiley and Sons, Inc.

Bitzer, D. L., Hicks, B. L., Johnson, R. L., & Lyman, E. R. (1967). The PLATO system: Current research and developments. *IEEE Transactions on Human Factors in Electronics, HFE-8*(2) 64-70.

Bitzer, D. L., Johnson, R. L., & Skaperdas, D. (1970). *A digitally addressable random-access image selector and random-access audio system.* Urbana, IL: University of Illinois Computer-based Education Research Laboratory.

Bitzer, D. L., & Skaperdas, D. (1971). The design of an economically viable large-scale computer-based education system. In R. E. Levien (Ed.). *Computers in instruction: Their future for higher education.* Santa Monica, CA: Rand.

Blaine, G. (1951). Biological teaching models and specimens. *Lancet, 261*, 337-340.

Blake, C. S. (1970). The work of a department of educational technology and programmed learning. In B. Lamb (Ed.) *New methods and media in further education.* London: Educational Foundation for Visual Aids.

Blatt, P. E., & Gum, D. R. (1986). Trends in ground-based and in-flight simulators fir development application. *Flight simulation: Agard conference proceedings No. 408.* Neuilly Sûr Siene, France: North Atlantic Treaty Organization.

Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain.* New York, NY: David McKay Company, Inc.

Board of Education of the North-West Territories. (1888). *Regulations of the board of education of the North-West Territories.* Regina: Government Printer.

Bonner, A. (Ed.). (1984). *Selected works of Ramon Llull (1232-1316), Vol. I.* Princeton, N.J.: Princeton University Press.

Boocock, S. S. (1968). Simulation games today. *Instructional Technology, 8*(8) 7-10.

Bork, A. (1981). *Learning with computers.* CA: Digital Press.

Bourne, L. E., Jr., & Ekstrand, B. R. (1976). *Psychology: Its principles and meanings.* New York, NY: Holt, Rinehart and Winston.

Bowers, J. (1991, April 14). Computer has the power to train the disabled. *Edmonton Examiner,* p. 6.

Boyce, J. C. (Ed.). (1947). *New weapons for air warfare.* Boston, MA: Little, Brown and Company.

Bratley, P., Fox, B. L., & Schrage, L. E. (1983). *A guide to simulation.* New York, NY: Springer-Verlag New York Inc.

Braunfeld, P. G. & Fosdick, L. D. (1962). The use of an automatic computer system in teaching. *IRE Transactions on Education, E-5*(3&4) 156-167.

Bray, R. S. (1986). Visual and motion cueing in helicopter simulation. *Flight simulation: Agard conference proceedings No. 408.* Neuilly Sûr Siene, France: North Atlantic Treaty Organization.

Breland, K., & Breland, M. (1961). The misbehavior of organisms. *American Psychologist, 16,* 681-684.

Brenner, L. P., & Agee, C. C. (1979). The symbiosis of PLATO and microcomputers. *Educational Technology,*

Bridgman, C. (1964). A lecture response device: A preliminary report on a key aspect of a co-ordinated teaching program in anatomy. *Journal of Medical Education, 39,* 132-139.

Bridwell, N. Z. (1967). Sullivan high school's auto tutor program. *Audiovisual Instruction, 12,* 489-491.

Briggs, L. J. (1947). Intensive classes for superior students. *The Journal of Educational Psychology, 36,* 207-215.

Briggs, L. J. (1958). Two self-instructional devices. *Psychological Reports, 4,* 671-676.

Briggs, L. J. (1959). Teaching machines for training of military personnel in maintenance of electronic equipment. In E. Galanter (Ed.) *Automatic teaching: The state of the art.* New York, NY: John Wiley & Sons, Inc.

Briggs, L. J. (1964). Don't oil your teaching machine. *Psychological Reports, 15,* 350.

Broadcasting system permits student feedback. (1966). *Educational Technology, 6*(10) 10-11.

Brockway, D. C., & Brockway, W. W. (1939). Survey of the school use of sound equipment. *The National Elementary Principal Thirteenth Yearbook: Aids to Teaching in the Elementary School, 13*(5) 418-425.

Brooker, F. E. (1957). The quiet revolution: A theory of tools. *Audio-Visual Instruction, 2,* 124-125.

Broudy, H. S. (1962). Teaching machines: Threats and promise. *Educational Theory, 12,* 151-156.

Brumbaugh, R. S. (1966). *Ancient Greek gadgets and machines.* New York: Thomas Y. Crowell Company.

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review, 31,* 21-32.

Bruner, J. S. (1964). The course of cognitive growth. *American Psychologist, 19,* 1-15.

Bruner, J. S. (1966). *Towards a theory of instruction.* Cambridge, MA: Harvard University Press.

Bruner, J. S. (1985). Models of the learner. *Educational Researcher, 14*(6) 5-8.

Buck, A. H. (1917). *The growth of medicine: From the earliest times to about 1800.* New Haven, CT: Yale University Press.

Buck, G. H. (1989). Teaching machines and teaching aids in the ancient world. *The McGill Journal of Education, 24*(1) 31-54.

Buck, G. H. (1991). Development of simulators in medical education. *Gesnerus: Swiss journal of the history of medicine and sciences, 48,* 7-28.

Budkin, A., & Warner, H. R. (1968). Computer assisted teaching of cardiac arrhythmias. *Computers and biomedical research, 2,* 145-150.

Bugelski, B. R. (1971). *The psychology of learning applied to teaching.* Indianapolis, IA: The Bobbs-Merrill Company, Inc.

Bullough, R. V., & Beatty, L. F. (1987). *Classroom applications of microcomputers.* Columbus, OH: Merrill Publishing Company.

Bunderson, C. V. (1973). *TICCIT project: Design strategy for educational innovation: ICUE technical report no. 4.* Provo, UT: Division of Instructional Research, Development & Evaluation, Brigham Young University.

Bunderson, C. V. (1977). *A rejoinder to the ETS evaluation of TICCIT, CTRC technical report no.* 22. Provo, UT: Brigham Young University.

Bunderson, C. V. (1981). Courseware. In H. O'Neil (Ed.) *Computer-based instruction: A state-of-the-art assessment.* New York: Academic Press.

Campbell, E. J., & Matthews, C. M. (1968). The use of computers to simulate the physiology of respiration. *British Medical Bulletin, 24*(3) 249-252.

Carpenter, C. R. (1953). A theoretical orientation for instructional film research. *Audio Visual Communication Review, 1*, 38-52.

Cartwright, G. F. (1991). A decade up, a decade down: Computers in the Faculty of Education. *McGill Journal of Education, 26*(2 - Supplement) 149-155.

Cavanagh, P. (1964). The autotutor and classroom instruction: Three comparative studies. *Programmed Learning, 1*(1) 26-31.

Ceruzzi, P. (1983). *Reckoners: The prehistory of the digital computer, from relays to the stored program concept, 1935-1945.* Westport, CT: Greenwood Press.

Chalmers, J. W. (1978). *Gladly would he teach: A biography of Milton Ezra LaZerte.* Edmonton: The ATA Educational Trust.

Chalmers, R. (1990, January 24). Modest beginnings shared by successful women. *The Edmonton Journal*, p. D14.

Chambers, J. A. & Sprecher, J. W. (1983). *Computer-assisted instruction: Its use in the classroom.* Englewood Cliffs, NJ: Prentice-Hall.

Chandor, A., Graham, J., & Williamson, R. (1977). *The Penguin dictionary of computers.* Harmondsworth: Penguin Books Ltd.

Chaplin, J. P. (1985). *Dictionary of psychology.* New York, NY: Dell Publishing.

Charlton, K. (1965). *Education in renaissance England.* London: Routledge and Kegan Paul.

Charp, S., & Wye, R. E. (1968). Philadelphia tries computer assisted instruction. *Educational Technology, 8*(9) 13-15.

Chevalier, U. (1907). *Répertoire des sources historiques du Moyen Age: Bio-bibliographie Volume II* [Listing of historical sources of the middle ages: Bio-bibliography Volume II]. New York, NY: Kraus Reprint Corporation, 1960.

Chew, V. K. (1973). *Talking machines.* London: Her Majesty's Stationery Office.

Chianfrani, T. (1960). *A short history of obstetrics and gynecology.* Springfield, IL: Charles C. Thomas.

Christian, G. L. (1951). PanAm building DC-6B flight simulator. *Aviation Week, 55*(21) 66-68.

Cicero, M. T. *De Natura Deorum.* (translated by H. Rackham, 1933). London: William Heinemann Ltd.

Cicero, M. T. *De Re Publica.* (translated by C. W. Keyes, 1928). London: William Heinemann Ltd.

Cicero, M. T. *Tusculan disputations.* (translated by A. E. Douglas, 1985). Warminster: Bolchazy Carducci Publishers.

Clare, L. (1983). *La quintaine, la course de bague et le jeu des têtes: Études historique et ethno-linguistique d'une famille de jeux équestres* [The quintaine, the race for the ring and the game of heads: Historical and ethno-linguistic study of a group of equestrian games]. Paris: Centre National De La Recherche Scientifique.

Clark, R. E. (1983). Reconsidering research on learning from media. *Review of Educational Research, 53,* 445-459.

Cleary, A., Mayes, T., and Packham, D. (1976). *Educational technology: Implications for early and special education.* London: John Wiley & Sons.

Cline, H. F. (1986). Background and design of the program. In H. F. Cline, et al., *The electronic schoolhouse: The IBM secondary school computer education program.* Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Cohen, S. (1961). Caution - Equipment buyers. *Audiovisual Instruction, 6,* 520 & 525.

Coleman, R. M. (1986). *Wide awake at 3:00 a.m.: By choice or by chance?* New York, NY: W. H. Freeman and Company.

Collis, B., & Muir, W. (1984). *Computers in education: An overview.* Victoria: University of Victoria.

Computerized driving simulator. (1967). *Educational Technology, 7*(21) 22-23.

Connolly, P. (1981). *Greece and Rome at war.* London: Macdonald Phoebus Ltd.

Control Data Corporation. (1976). *Control Data Corporation's activities in the field of education.* Minneapolis, MN: Author.

Control Data Corporation. (1979). *CDC© information systems terminal II: Hardware maintenance manual (site support information).* St. Paul, MN: Author.

Control Data Corporation. (1980). *PLATO courses.* St. Paul, MN: Author.

Control Data Corporation. (1983). PLATO educational courseware brings new excitement to learning: advertisement. *Compute!, 5*(9) 43.

Conway, P. A. (1976). *Control Data enters computer-based education field.* Minneapolis, MN: Control Data Corporation.

Corey, S. M. (1967). The nature of instruction. In P. C. Lange (Ed.) *Programmed instruction: The sixty-sixth yearbook of the National Society for the study of education: Part II.* Chicago, IL: University of Chicago Press.

Corno, L., & Snow, R. E. (1986). Adapting teaching to individual differences among learners. In M. C. Wittrock (Ed.) *Handbook of research on teaching* (3rd ed.). New York, NY: Macmillan.

Coulson, J. E. (1960). *Automatic teaching project: Description of experimental equipment.* Santa Monica, CA: System Development Corporation.

Coulson, J. E. (1962). A computer-based laboratory for research and development in education. In J. E. Coulson (Ed.) *Programmed learning and computer-based instruction: Proceedings of the conference on application of digital computers to automated instruction.* New York, NY: John Wiley and Sons, Inc.

Coulson, J. E. (1966). Applications of information processing. *Educational Technology, 6*(19) 1-10.

Coulson, J. E., & Silberman, H. F. (1959a). *Results of an initial experiment in automated teaching.* Santa Monica, CA: System Development Corporation.

Coulson, J. E., & Silberman, H. F. (1959b). *Proposal for extension of automated teaching project.* Santa Monica, CA: System Development Corporation.

Cowper, D., & Romaniuk, E. W. (1975). *Beginner's guide to the DERS CAI system.* Edmonton: Division of Educational Research Services, Faculty of Education, University of Alberta.

Craig Research, Inc. (1961). A better way to improve reading: advertisement. *Audiovisual Instruction, 6*, 483.

Cram, D. (1961). *Explaining "teaching machines" and programming.* Palo Alto, CA: Fearon Publishers.

Crane, R., Yates, M., & Steen, S. N. (1968). An improved electronic simulator for the study of the distribution of anæsthetic agents. *British Journal of Anæsthesia, 40*, 936-942.

Crossman, D. M. (1963). Fix it so it will work!: A report of an experiment with a classroom response system. *Audiovisual Instruction, 8*, 596-601.

Crowder, N. A. (1959). Automatic tutoring by means of intrinsic programming. In E. Galanter (Ed.) *Automatic teaching: The state of the art.* New York, NY: John Wiley & Sons, Inc.

Crowder, N. A. (1960). Automatic tutoring by intrinsic programming. In A. A. Lumsdaine & R. C laser (Eds.) *Teaching machines and programmed learning: A source book.* Washington, DC: National Education Association of the United States.

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920.* New York, NY: Teachers College Press.

Cuff, N. B. (1927). *The relation of overlearning to retention.* Nashville, TN: George Peabody College for Teachers.

Dale, E. (1954). *Audiovisual methods in teaching.* London: Holt, Rinehart and Winston.

Daremberg, C., & Saglio, E. (1896). *Dictionnaire des antiquités Grecques et Romaines* [Dictionary of Greek and Roman antiquities]. Paris: Boccard.

Darlington, O. G. (1947). Gerbert, the teacher. *The American Historical Review, 52*(3) 456-476.

Darrow, B. (1932). *Radio: The assistant teacher.* Columbus, OH: R. G. Adams.

D'Attore, A. (1981). Computer aided instruction, boon or bust? *Compute!, 3*(5) 18-20.

Daumas, M. (1972). *Scientific instruments of the seventeenth and eighteenth centuries and their makers.* London: B. T. Batsford.

Davis, F. B. (1948). Psychological research in the AAF aviation psychology program. *Review of Educational Research, 18*(6-special) 543-574.

De Cecco, J. P. (Ed.). (1964). *Educational technology: Readings in programmed instruction.* New York, NY: Holt, Rinehart and Winston.

De Forest-Sanabria Corporation. (1951). Television right at home!: advertisement. *Radio & Television News*, February, p. 7.

Denson, J. S., & Abrahamson, S. (1969). A computer-controlled patient simulator. *Journal of the American Medical Association, 208* 504-508.

Dent, E. C. (1942). *The audio-visual handbook.* Chicago, IL: Society for Visual Education, Inc.

Dent, L. M. (1914). Are the Montessori claims justified? *Forum, 51*, 883-891.

Department of Education of the North-West Territories. (1903). *Annual report.* Regina: Government Printer.

Deterline, W. A. (1962). *An introduction to programed instruction.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Deutsch, W. (1962). Programed learning: An overview of personnel and financial requirements. In S. Margulies & L. Eigen (Eds.) *Applied programed instruction.* New York, NY: John Wiley and Sons, Inc.

DeVry Corporation. (1921). Applying motion pictures: advertisement. *School Board Journal, 63*(3) 101.

Dimmick, F. D. (1977). *Computer assisted instruction at the Pennsylvania State University, 1964-1977: A program history.* University Park, PA: The Pennsylvania State University College of Education.

Dizziness probed in CF-18 crashes. (1990, June 14). *Edmonton Journal*, p. A14.

Dobbs, E. V. (1930). Helps that hinder. *School and Community, 16*, 80-81.

Doron Precision Systems. (1988a). *SR2 specifications.* Binghamton, NY: Author.

Doron Precision Systems. (1988b). *SR2 library of programs.* Binghamton, NY: Author.

Doron Precision Systems. (1990). *Keeping pace with tomorrow.* Binghamton, NY: Author.

Dorsett, L. G. (1971). *Audio-visual teaching machines.* Englewood Cliffs, N.J.: Educational Technology Publications.

Doty, A. B., Heintzman, R. J., Steedman, W. C., & Schiffler, R. J. (1969). Experience in visual simulation with implications for a systematic approach to development. *Photo-optical techniques in simulators: S.P.I.E. seminar proceedings, Volume 17.* ?: Society of Photo-Optical Instrumentation Engineers.

Dummer, G. W. A., & Robertson, J. M. (1967). *Educational electronics equipment.* Oxford: Pergamon Press.

Du Kane Corporation. (1966). Incomparable sight and sound by Dukane: advertisement. *Audiovisual Instruction, 11*, 157-158.

Duncan, K. D. (1964). Experiments with an inexpensive device for programmed instruction in the multiple-choice branching style. *Programmed Instruction, 1,* 145-154.

Dunlap, O. E., Jr. (1932). *The outlook for television.* New York: Harper & Brothers Publishers.

Durrett, J., & Stimmel, T. (1982). The instructional use of color. *Pipeline, 7*(2) 10-16.

Eastman Kodak Company. (1979). *Preservation of photographs.* Rochester, NY: Author.

Ebbinghaus, H. (1885/1913). *Über das Gedächtnis* [On memory] (H. A. Ruger & C. E. Busenius, Trans.). New York, NY: Teachers College. Columbia University. (Original published, 1885).

Ebeling, F. A., Goldhor, R. S., & Johnson, R. L. (1972). A scanned infrared light beam touch entry system. *Proceedings*, Society for Information Display, 134-135.

Eckstrand, G. A., Rockway, M. R., Kopstein, F. F., & Morgan, R. L. (1961). *Teaching machines in the modern military organization.* Wright-Patterson Air Force Base, OH: United States Air Force.

Edelman, B. (1958). Education is the 'core' problem that industry must face. *IRE Transactions on Education, E-1*(4) 99-103.

Edmonton Journal. (1990, January 31). "Television working its way into the classroom", p. C10.

Einbecker, W. F. (1933). Comparison of verbal accompaniments to films. *School Review, 41*, 185-192.

Electrical Research Products Inc. (1930). Are talking pictures in your blueprints?: advertisement. *School Board Journal, 8*(1) 83.

Electrolab. (1975). *Technology training equipment catalogue.* Belleville: Author.

Ellison, J. W., & Coty, P. A. (1987). Simulation materials. In J. Ellison & P. Coty (Eds.) *Nonbook media: Collection and user services.* Chicago, IL: American Library Association.

Elmore, R. F. (1978). Organizational models of social program implementation. In D. Mann (Ed.) *Making change happen?* New York, NY: Teachers College Press.

English, H. B. (1942). How psychology can facilitate military training – A concrete example. *The Journal of Applied Psychology, 26,* 3-7.

English, W. K., Engelbart, D. C., & Berman, M. L. (1967). Display-selection techniques for text manipulation. *IEEE Transactions on Human Factors in Electronics, HFE-8*(1) 5-15.

Epstein, S. & Epstein, B. (1961). *The first book of teaching machines.* New York, NY: Franklin Watts, Inc.

Erasmus, D. (1985). A declamation of the subject of early liberal education for children. In J. K. Sowards (Ed.) *Collected works of Erasmus.* Toronto: University of Toronto Press.

Erikson, E. H. (1977). *Toys and reasons.* New York, NY: W. W. Norton & Company.

Everett, R. R. (1980). Whirlwind. In N. Metropolis, J. Howlett, & G-C. Rota (Eds.) *A history of computing in the twentieth century.* New York, NY: Academic Press.

Ewy, G. A., Felner, J. M., Juul, D., Mayer, J. W., Sajid, A. W., & Waugh, R. A. (1987). Test of a cardiology patient simulator with students in fourth-year electives. *Journal of Medical Education, 62,* 738-743.

Farley, F. H., & Grant, A. P. (1976). Arousal and cognition: Memory for color versus black and white multimedia presentation. *Journal of Psychology, 94*(1) 147-150.

Feer, M. (1985). *A computer-based curriculum for head-injured students, intended for implementation in the Massachusetts public schools.* Boston, MA: Massachusetts State Department of Education, ERIC document ED 263697.

Feldhusen, J. F. (1963). Taps for teaching machines. *Phi Delta Kappan, 44,* 265-267.

Feldhusen, J. F., & Szabo, M. (1969). A review of developments in computer assisted instruction. *Educational Technology, 9*(4) 32-39.

Ferrington, G., & Loge, K. (1992). Virtual reality: A new learning environment. *The Computing Teacher, 19*(7) 16-19.

Ferster, C. B., & Sapon, S. M. (1958). An application of recent developments in psychology to the teaching of German. *Harvard Educational Review, 28,* 58-69.

Festinger, L. (1957). *A theory of cognitive dissonance.* Stanford, CA: Stanford University Press.

Findley, P. (1939). *The priests of lucina: The story of obstetrics.* Boston, MA: Little, Brown & Company.

Fine, B. (1962). *Teaching machines.* New York, NY: Sterling Publishing Co., Inc.

Fines, J., & Verrier, R. (1974). *The drama of history.* London: New University Education Press.

Finn, J. D. (1960). Technology and the instructional process. *Phi Delta Kappan, 41,* .

Finn, J. D., & Perin, D. G. (1962). *Teaching machines and programed learning: A survey of the industry.* Washington, DC: U.S. Department of Health, Education, and Welfare.

Fletcher, S. S. F., & Welton, J. (1912). *Froebel's chief writings on education rendered into English.* New York, NY: Longman's, Green & Co.

Foltz, C. I. (1961). *The world of teaching machines.* Washington, DC: Electronic Teaching Laboratories.

Forester, T., & Morrison, P. (1990). *Computer ethics: Cautionary tales and ethical dilemmas in computing.* Cambridge, MA: The MIT Press.

Foster, C. (1983). An analysis of the rise and fall of programmed instruction. Implications for computer-assisted instruction. *Journal of Special Education Technology, 6*(1) 5-14.

Fox, J. H. (1960). *Driver education and driving simulators.* Washington, DC: National Commission on Safety Education, National Education Association.

Francis, L. (1976). *PLATO IV terminal peripheral devices.* Urbana, IL: Computer-based Education Research Laboratory, University of Illinois.

Friedrich, H. (1986). Operational training: Application and experience. *Flight simulation: Agard conference proceedings No. 408.* Neuilly Sûr Siene, France: North Atlantic Treaty Organization.

Frontinus, S. J. *Strategemata.* In *The strategies and the aqueducts of Rome* (translated by C. E. Bennett, 1925). London: William Heinemann.

Fry, E. B. (1963). *Teaching machines and programmed instruction: An introduction.* New York, NY: McGraw-Hill Book Company, Inc.

Fry, E. B., Bryan, G. L., & Rigney, J. W. (1960). Teaching machines: An annotated bibliography. *Audio-Visual Communication Review, 8,* 1-80.

Gaba, D. A., & DeAnda, A. (1987). Anesthesia simulation in an actual operating room environment. *Anesthesiology, 67,* A467.

Gage, N. L., & Berliner, D. C. (1988). *Educational psychology.* Boston, MA: Houghton Mifflin Company.

Gagné, R. M. (1954). Training devices and simulators: Some research issues. *American Psychologist, 9,* 95-107.

Gagné, R. M. (1962). Military training and principles of learning. *American Psychologist, 17,* 83-91.

Gagné, R. M. (1965). The analysis of instructional objectives for the design of instruction. In R. Glaser (Ed.) *Teaching machines and programed learning, II: Data and directions.* Washington, DC: National Educational Association of the United States.

Gagné, R. M. (1984). Learning outcomes and their effects: Useful categories of human performance. *American Psychologist, 20*(10) 377-385.

Gagné, R. M. (Ed.). (1987). *Instructional Technology: Foundations.* Hillsdale, NJ: Lawrence Earlbaum Associates.

Gagné, R. M., & Bolles, R. C. (1959). A review of factors in learning efficiency. In E. Galanter (Ed.) *Automatic teaching: The state of the art.* New York, NY: John Wiley & Sons, Inc.

Gaines, B. R., & Shaw, M. L. G. (1986). From timesharing to the sixth generation: The development of human-computer interaction. Part 1. *International Journal of Man-Machine Studies, 24,* 1-27.

Gal'perin, П. Я. (1967). *К теории программированного обучения* [Theories of programmed instruction]. Moscow.

Garner, W. L. (1966). *Programmed instruction.* New York, NY: The Center for Applied Research in Education, Inc.

Gee, R. D. (1963). *Teaching machines and programmed learning: A guide to the literature.* Hatfield, Herts: Hertfordshire County Council.

Geis, G. L. (1987). Comprehensive history of teaching machines. *Performance & Instruction, 26*(5) 3.

General Dynamics. (1989). The new teacher has 137 microchips, an infrared sensor, and little rubber wheels: Advertisement. *New Yorker Magazine*, October 9, p. 24.

Gibbs, G. I. (1975). Gaming, simulation and the sciences. In G. I. Gibbs & A. Howe (Eds.) *Academic Gaming and simulation in education and training.* London: Kogan Page.

Gibbs, S., & Saliba, G. (1984). Planispheric astrolabes from the National Museum of American history. *Smithsonian Studies in History and Technology, 45.*

Gilbert, T. F. (1979). Human incompetence: The autobiography of an educational revolutionist. *National Society for Performance and Instruction Journal, 18*(6) 15-21.

Gille, F. H. (Ed.). (1965). *Automated education handbook.* Detroit, MN: Automated Education Center.

Gilligan, J. (1975). Computer assisted learning in ICL. In R. Hooper & I. Toye (Eds.) *Computer assisted learning in the United Kingdom.* London: CET National Development Programme in Computer Assisted Learning.

Gingerich, O. (1986). Islamic astronomy. *Scientific American, 254*(4) 74-83.

Glaser, R. (1960). Christmas past, present and future: A review and preview. In A. A. Lumsdaine & R. Glaser (Eds.) *Teaching machines and programmed learning: A source book.* Washington, DC: National Education Association of the United States.

Glaser, R. (1962). Some research problems in automated instruction: Instructional programming and subject-matter structure. In J. E. Coulson (Ed.) *Programmed learning and computer-based instruction: Proceedings of the conference on application of digital computers to automated instruction.* New York, NY: John Wiley and Sons, Inc.

Glaser, R. (1965). Toward a behavioral science base for instructional design. In R. Glaser, Ed., *Teaching machines and programmed learning, II: Data and directions.* Washington, DC: National Education Association of the United States.

Glaser, R., Damrin, D. E., & Gardner, F. M. (1954). The tab item: A technique for the measurement of proficiency in diagnostic problem-solving tasks. *Educational and Psychological Measurement, 14,* 283-293.

Gleason, G. T. (1967). Computer assisted instruction: Prospects and problems. *Educational Technology, 7*(21) 1-8.

Goebel, L. G. (1961). A simple device for Skinner disc programs. *Audiovisual Instruction, 6,* 133.

Goodman, R. (1963). *Programmed learning and teaching machines: An introduction.* London: The English Universities Press Ltd.

Gordon, A. S. (n.d.). *A death mask to help save lives: The story of Resusci-Anne.* Armonk, NY: Laerdal Medical Corporation.

Gordon, M. S. (1974). Cardiology patient simulator: Development of an animated manikin to teach cardiovascular disease. *American Journal of Cardiology, 34,* 350-355.

Gordon, M. S., Ewy, G. A., DeLeon, A. C. Jr., Waugh, R. A., Felner, J. M., Forkner, A. D., Gessner, I. H., Mayer, J. W., & Patterson, D. (1980). Harvey, the cardiology patient simulator: Pilot studies in on teaching effectiveness. *American Journal of Cardiology, 45,* 791-796.

Gould, M. P. (1915). *Frank Hornby: The boy who made $1,000,000 with a toy.* London: New Cavendish Books, 1975.

Gravenstein, J. S. (1988). Training devices and simulators. *The Journal of Anesthesiology, 69*(3) 295-297.

Graves, F. P. (1914). Is the Montessori method a fad? *Popular Science Monthly, 84,* 609-614.

Graves, F. P. (1918). *A history of education before the middle ages.* New York, NY: The Macmillan Company.

Green, E. J. (1963). *The learning process and programmed instruction.* New York, NY: Holt, Rinehart and Winston, Inc.

Gunther, R. T. (1923a; reprinted 1967). *Early science in Oxford: Volume I, chemistry, mathematics, physics and surveying.* London: Dawsons of Pall Mall.

Gunther, R. T. (1923b; reprinted 1967). *Early science in Oxford: Volume II, astronomy.* London: Dawsons of Pall Mall.

Gunther, R. T. (1937; reprinted 1969). *Early science in Cambridge.* London: Dawsons of Pall Mall.

Guthrie, E. R. (1942). Conditioning: A theory of learning in terms of stimulus, response, and association. In N. B. Henry (Ed.) *The forty-first yearbook of the National Society for the study of education: Part II, the psychology of learning.* Chicago, IL: University of Chicago Press.

Guthrie, E. R., & Powers, F. F. (1950). *Educational psychology.* New York, NY: Ronald Press.

Haller, G. L. (1966). Educational technology and industry. *Educational Technology, 6*(16) 13-16.

Handel, S. (1971). *A dictionary of electronics.* Harmondsworth: Penguin Books Ltd.

Hankin, G. T. (1931). Mechanical aids to education. *New Era: An International Review of New Education, 12,* 261-263.

Hanson, L. F., & Komoski, P. K. (1965). School use of programed instruction, in R. Glaser (Ed.), *Teaching machines and programed learning, II: Data and directions.* Washington, D.C.: National Education Association of the United States.

Harless, W. G., Zier, M. A., & Duncan, R. C. (1986). A voice-activated, interactive videodisc case study for use in the medical school classroom. *Journal of Medical Education, 61*(11) 913-915.

Harrison, M. (1942). *Radio in the classroom: Objectives, principles, and practices.* New York, NY: Prentice-Hall, Inc.

Hartman, T. F. (1966). Computer assisted instruction. *Audiovisual Instruction, 11,* 22-23.

Hartner, W. (1965). The principle and use of the astrolabe, in A. Pope, *A survey of Persian art, Vol. 6.* London: Oxford University Press.

Havelock, R. G., & Huberman, A. M. (1977). *Solving educational problems: The theory and reality of innovation in developing countries.* Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO).

Haward, D. M. (1910). The Sanders "teacher". *Flight, 2*, 1006-1007.

Hayward, F. H. (1904). *The educational ideas of Pestalozzi and Fröbel.* London: Ralph, Holland & Co.

Hebb, D. O. (1955). Drive and the CNS (conceptual nervous system). *Psychological Review, 62*, 243-354.

Heines, J. M. (1988). Milestones in early learning devices. *CoAction, 1*(1) 24-29.

Helmers, C. (1978). Some enticing advance words. *Byte, 3*(3) 6.

Hendershot, C. H. (1964). *Programmed learning: A bibliography of programs and presentation devices.* Bay City, MI: Author.

Hendershot, C. H. (1967). *Programmed learning: A bibliography of programs and presentation devices.* Bay City, MI: Author.

Hendershot, C. H. (1969). *Programmed learning: A bibliography of programs and presentation devices.* Bay City, MI: Author.

Henderson Directories Alberta Ltd. (1913). *Henderson's greater Edmonton city directory for 1913.* Edmonton: Author.

Hendry, G. M., Co. (1920). School equipment advertisement. *The A.T.A. Magazine, 1*(6) 19.

Henry, W. G., Jr. (1961). What makes a teaching machine teach? *Audiovisual Instruction, 6*, 126-129, 145.

Hergenhahn, B. R. (1988). *An introduction to theories of learning* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Hero. *Opera* (W. Schmidt, Ed.; 1899, reprinted 1976). Stuttgart: B. G. Tuebner.

Herriott, J. (1985). *The book of ICON.* Toronto: John Wiley & Sons.

Hilgard, E. R. (1971). The psychological heuristics of learning. In S. G. Tickton, *To improve learning: An evaluation of instructional technology, Volume II.* New York: R. R. Bowker Company.

Hilloowala, R., & Renahan, J. (1985). XVIII century anatomical models at La Specola, Florence. *Anatomischer Anzeiger, 159*, 141-158.

Hilton, G. W. (1982). *The cable car in America.* San Diego, CA: Howell-North Books.

Himwich, H. A. (1977). *A comparison of the TICCIT and PLATO® systems in a military setting.* Urbana, IL: Computer-based Education Research Laboratory, University of Illinois.

Hlady, A. M. (1968). *A touch-sensitive X-Y position encoding overlay for computer input.* Ottawa: National Research Council of Canada.

Hlebowitsh, P. S. (1988). Technology in the classroom: Cautionary notes on a recurring theme. *The Clearing House, 62*, 53-58.

Hobbs, N. (1947). Psychological research on flexible gunnery training. *AAF aviation psychology program research projects, report no. 11.* Washington, DC: Government Printing Office of the United States.

Hock, C. F. (ca. 1850). *Histoire du Pape Sylvestre II et de son siècle.* Paris: Debécourt, Libraire-Éditeur.

Hoffman Information Systems. (1967). A new assistant for the teacher: advertisement. *Audiovisual Instruction, 12*(1) 67.

Holland, J. G. (1962). Teaching machines: An application of principles from the laboratory. In W. I. Smith and J. W. Moore (Eds.) *Programmed learning: Theory and research.* Princeton, NJ: D. Van Nostrand Company, Inc.

Holland, W. B., & Hawkins, M. L. (1972). Technology of computer uses in education. In R. E. Levien (Ed.) *The emerging technology: Instructional uses of the computer in higher education.* New York, NY: McGraw-Hill Book Company.

Holling, K. (1967). The feedback classroom in use. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology.* London: Methuen & Co. Ltd.

Hollis, R. (1977). Newt: A mobile, cognitive robot. *Byte, 2*(6) 30-45.

Holstein, G. N. (1965). Simulation in driver education. *Teaching Aids News, 5*(18) 7-15.

Holte, J. (c. 1496). *Lac Puerorum* [Milk for children].

Hooper, R., & Toye, I. (Eds.). (1975). *Computer assisted learning in the United Kingdom: Some case studies.* London: Council for Educational Technology.

Horace (Quintus Horatius Flaccus). *Satires.* In *Rolfe's satires and epistles of Horace* (introduction by J. C. Rolfe, 1901). Boston, MA: Allyn and Bacon.

Hosmer, C. L., & Nolan, J. A. (1962). Time saved by a tryout of automatic tutoring. In S. Margulies & L. Eigen (Eds.) *Applied programed instruction.* New York, NY: John Wiley and Sons, Inc.

Hudson, A. D. (1983). A hypochlorite solution for removing bacteria from CPR manikins. *Annals of Emergency Medicine, 12*, 485-488.

Huff, E. M., & Nagel, D. C. (1975). Psychological aspects of aeronautical flight simulation. *American Psychologist, 30*, 426-444.

Hughes Aircraft Company. (1964). Training with Hughes videosonic systems: advertisement. *Audiovisual Instruction, 9*, 631.

Hunka, S. M. (1962). Book review. *Alberta Journal of Educational Research, 8*(3) 185.

Hunka, S. M. (1968). *CAI - the technical aspects: An educational innovator's viewpoint.* Edmonton: University of Alberta, Division of Educational Research Services.

Hunka, S. M. (1977). *Eight years of computer-assisted instruction: Now what?* RIR-77-6. Edmonton: University of Alberta, Division of Educational Research Services.

Hunka, S. M. (1990). Sixteen years of teaching elementary applied statistics using CAI: A case study. *Journal of Educational Technology Systems, 19*, 139-150.

Hunka, S. M., & Romaniuk, E. W. (1973). The environment for computer assisted instruction. *Journal of Clinical Computing,* 2(4) 56-67.

Hunka, S. M., & Romaniuk, E. W. (1974). Computer assisted instruction. *Canadian Datasystems, 6*(6) 17-21.

Hunter, I. (1990, April 21). Forces' pilots still confident. *Edmonton Journal,* p. G2.

IBM announces computer system for education. (1966). *Educational Technology, 6*(9) 16-19.

International Business Machines Corporation. (1966). *Technical information exchange: The IBM 1500 instructional system.* White Plains, NY: Author.

International Business Machines Corporation. (1967). *Original equipment manufacturers' information: IBM 1131 central processing unit, IBM 1133 multiplex control enclosure storage access chanel.* San José, CA: Author.

International Business Machines Corporation. (1968). *IBM 1500 instructional system, system summary.* San José, CA: Author.

International Business Machines Corporation. (1969). *IBM 1506 Audio unit operating procedures and tape preparation guide.* San José, CA: Author.

Iverson, K. E. (1966). *Elementary functions: An algorithmic treatment.* Chicago, IL: Science Research Associates.

Jameson, E. M. (1936). Gynecology and obstetrics. *Clio Medica, 17,* 35-37.

Jenkinson, W., & Browning, C. (1970). Programmed learning on a shoestring. In B. Lamb (Ed.) *New methods and media in further education.* London: Educational Foundation for Visual Aids.

Jevons, W. S. (1870). On the performance of logical inference. *Philosophical Transactions of the Royal Society of London.*

Jevons, W. S. (1877). *The principles of science: A treatise on logic and scientific method.* Reprinted, 1958. New York, NY: Dover Publications.

Johnson, D. M. (1961). *Psychology: A problem-solving approach.* New York, NY: Harper & Row, Publishers.

Johnstone, R. W. (1952). *William Smellie, the master of British midwifery.* Edinburgh: E. & S. Livingstone.

Jonassen, D. H. (1985). Learning strategies: A new educational technology. *Programmed Learning and Educational Technology, 1,* 26-34.

Jonassen, D. H. (1987). Programmed materials. In J. W. Ellison & P. A. Coty (Eds.) *Nonbook media: Collection management and user services.* Chicago, IL: American Library Association.

Jonassen, D. H. (1988). (Ed.). *Instructional designs for microcomputer courseware.* Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Johnston, J. (1987). *Electronic learning: From audiotape to videodisc.* Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Jones, D. (1980). *Toy with the idea: Teaching toys from the collection of the Norfolk museums service.* Norfolk: Norfolk Museums Service.

Jordan, W. C. (1966). Six-year-olds reading faster, better with electronic aids. *Audiovisual Instruction, 11,* 542-543.

Judd, C. H. (1918). *Introduction to the scientific study of education.* Boston, MA: Ginn and Company.

Judd, C. H. (1923). *Report of the committee on visual education and cooperation with the Motion Picture Producers and Distributors, Inc., to the National Education Association.* Washington, DC: National Education Association.

Judd, C. H. (1932). Autobiography. In C. Murchison (Ed.) *A history of psychology in autobiography: Volume II.* Worcester, MA: Clark University Press.

Juvenal. *Satires* (commentary by J. Ferguson, 1979). New York, NY: St. Martin's Press.

Kay, H., Dodd, B., & Sime, M. (1968). *Teaching machines and programmed instruction.* Harmondsworth, Middlesex: Penguin Books Ltd.

Keislar, E. R. (1959). The development of understanding in arithmetic by a teaching machine. *Journal of Educational Psychology, 50,* 247-253.

Keller, F. S. (1968). Good-bye teacher. *Journal of Applied Behavior Analysis, 1,* 69-89.

Kelly, L. L., & Parke, R. B. (1970). *The pilot maker.* New York, NY: Grosset & Dunlap.

Kemeny, J. A. (1955). Man viewed as a machine. *Scientific American, 192,* April, 58-67.

Kemp, F. G. (1967). Innovations in the assessment of programmed instruction. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology.* London: Methuen & Co. Ltd.

Kennedy, E. S. (1960). *The planetary equatorium of Jamshid Ghiyath Al-Din Al-Kashi.* Princeton, NJ: Princeton University Press.

Kepner, H. S., Jr. (1986). Issues regarding computers in the schools. In H. S. Kepner, Jr. (Ed.) *Computers in the classroom.* Washington, DC: National Education Association.

Kersh, B. Y. (1961). The classroom simulator: An audiovisual environment for practice teaching. *Audiovisual Instruction, 6,* 447-448.

King, H. C., & Millburn, J. R. (1978). *Geared to the stars: The evolution of planetariums, orreries, and astronomical clocks.* Toronto: University of Toronto Press.

Klass, P. (1952a). Link simulator boosts B-47 potential. *Aviation Week, 56*(24) 65-70.

Klass, P. (1952b). New airline boom in flight simulators. *Aviation Week, 57*(3) 81-82.

Kleiman, G. (1982). Teaching Johnny to program. *Compute!, 4*(7) 88-91.

Kneller, G. F. (1962). Automation and learning theory. *The School Review, 70,* 220-232.

Knight, M. A. (1963). The autotutor and classroom instruction. *Occupational Psychology, 37,* 44-48).

Knight, M. A. (1964). A note on the use of programmed instruction on a fault-finding training course. *Programmed Learning, 1,* 134-144.

Knowlton, D. C., & Tilton, J. W. (1929). *Motion pictures in history teaching.* New Haven, CT: Yale University Press.

Koenigsberg, A. (1990). *The patent history of the phonograph, 1877-1912.* Brooklyn, NY: APM Press.

Kohlberg, L. (1971). From is to ought. In T. Mischel, (Ed.) *Cognitive development and epistemology.* New York, NY: Academic Press.

Koncept-O-Graph Company. (1961). Teachers can concentrate on the more creative art of illuminating the material: advertisement. *Audiovisual Instruction, 6,* 175.

Koncept-O-Graph Company. (1962). Teaching machines give the teacher more time for teaching!: advertisement. *Audiovisual Instruction, 7,* 403.

Kovács, M., & Terényi, L. (1967). Didaktomat, a feedback device for controlling classroom activities of groups. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology.* London: Methuen & Co. Ltd.

Kretzschmer, F. (1978). *Bilddokumente Römischer technik* [Illustrated document of Roman technology]. Düsseldorf: Verlag des Vereins Deutscher Ingenieure.

Kuret, N. (1963). *La quintaine des Slovènes de la valée de la Zilia (Gailtal), et son cadre européen* [The quintain of the Slovenes of the Valley of the Zilia, and their European equivalents]. Ljubljana: Institut za Slovensko Narodopisje, Institutum Ethnographiae Slovenorum.

Lacroix, P. (1877). *Sciences & lettres au moyen age et l'époque de la renaissance* [Science and literature of the middle ages and the epoch of the renaissance]. Paris: Librairie de Firmin-Didot et Cie.

Lacy, J. V. (1919). The relative value of motion pictures as an educational agency. *Teachers College Record, 20,* 452-465.

Laerdal Medical. (1989a). *Resuscitation training aids and emergency equipment catalog.* Armonk, NY: Author.

Laerdal Medical. (1989b). *Laerdal airway management trainer, information sheet.* Armonk, NY: Author.

Lally, M. (1982). Computer-assisted handwriting instruction and visual kinaesthetic feedback processes. *Applied Research in Mental Retardation, 3,* 397-405.

Landa, L. N. (1973). Programmed instruction in the Soviet Union. In T. C. Helvey & F. F. Kopstein (Eds.) *The educational technology review series: Number 10: Using programmed instruction.* Englewood Cliffs, NJ: Educational Technology Publications.

Lashley, K. S., & Watson, J. B. (1922). *A psychological study of motion pictures in relation to venereal disease campaigns.* Washington, DC: United States Interdepartmental Social Hygiene Board.

Lattin, H. P. (1961). *The letters of Gerbert with his papal privileges as Sylvester II.* New York, NY: Columbia University Press.

Lawson, D. R. (1973). Who thought of it first? A review of historical references to programmed instruction. In *The educational technology reviews series: Number ten, using programmed instruction.* Englewood Cliffs, NJ: Educational Technology Publications.

LaZerte, M. E. (1922). Elementary Mathematics. *The A.T.A. Magazine Easter Annual, 1922,* 30.

LaZerte, M. E. (1926). *A study of the methods used by elementary school pupils in solving problems in arithmetic.* Edmonton: Unpublished BEd. thesis, University of Alberta, Edmonton.

LaZerte, M. E. (1927). *A diagnosis of difficulties encountered in solving problems in arithmetic.* Unpublished PhD. dissertation, University of Chicago, Chicago.

LaZerte, M. E. (1933). *The development of problem solving ability in arithmetic: A summary of investigations*. Toronto: Clarke, Irwin & Company Limited.

LaZerte, M. E. (1937). Primary number booklets. In *Catalogue of publications, 1937-1938*. Edmonton: The Institute of Applied Art, Ltd., Educational Publishers.

LaZerte, M. E. (1939). Reorganization in Canada. *The Phi Delta Kappan*, *22*, 120-123.

LaZerte, M. E. (1953). *Numbers tell their story*. Toronto: Clarke, Irwin & Company Limited.

LaZerte, M. E., Dey, J. D., & Svidal, R. (1959) *Numbers tell their story: Grade one teacher's manual*. Toronto: Clarke, Irwin & Company Limited.

Leavens, D. H. (1920). The Chinese suan-pan. *American Mathematical Monthly*, *27*, 180-184.

Lee, C. E. (1973). *The Piccadilly line*. London: London Transport.

Lee, V. (1970). Pupils like using teaching machines. *Mansfield News Journal*, March 26, p. 37.

Leedham, J. (1967). A summary of research and development with programmes and machines in Leicestershire since 1960. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology*. London: Methuen & Co. Ltd.

Lefrancois, G. R. (1982). *Pedagogical theories and human learning*. Monterey, CA: Brooks/Cole Publishing Company.

Lefrancois, G. R. (1988). *Psychology for teaching: A bear ~~always usually sometimes rarely never~~ always faces the front*. Belmont, CA: Wadsworth Publishing Company.

Lenkoff, C. B., & Garrett, C. L. (1986). *Revised yes & know invisible ink quiz & game book for ages 15-115*. Louisville, KY: Lee Publications.

Leverenz, H. W., & Townsley, M. G. (1963). *The design of instructional equipment: Two views*. Washington, DC: National Education Association.

Levin, E. (1989). Grand challenges to computational science. *Communications of the ACM*, *32*, 1456-1459.

Levine, H., & Rheingold, H. (1987). *The cognitive connection: Thought and language in man and machine*. New York, NY: Prentice-Hall Press.

Lewis, B. N., & Pask, G. (1965). The theory and practice of adaptive teaching systems. In R. Glaser (Ed.) *Teaching machines and programmed learning, II: Data and directions*. Washington, DC: National Education Association of the United States.

Lewis, R. (1975). Computers as a resource for learning. In R. Hooper & I. Toye (Eds.) *Computer assisted learning in the United Kingdom: Some case studies*. London: Council for Educational Technology.

Lindsley, D. B., et al. (1944). *A study of the SCH-584 basic trainer as a tracking device for learning range tracking*. Orange Park, FA: U. S. Office of Scientific Research and Development.

Licklider, J. C. (1962). Preliminary experiments in computer-aided teaching. In J. E. Coulson (Ed.) *Programmed learning and computer-based instruction: Proceedings of the conference on application of digital computers to automated instruction*. New York, NY: John Wiley and Sons, Inc.

Link Manufacturing Company. (1939). *Link trainer handbook of instructions*. Binghamton, NY: Author.

Link Manufacturing Company. (1942). *Link trainer handbook of instructions*. Binghamton, NY: Author.

Little, J. K. (1934). Results of use of machines for testing and for drill, upon learning in educational psychology. *Journal of Experimental Education, 3*, 45-49.

Locke, J. (1927). *Some thoughts concerning education*. Cambridge: The University Press.

Lockard, J., Abrams, P. D., & Many, W. A. (1987). *Microcomputers for education*. Boston, MA: Little, Brown and Company.

Loftus, G. R., & Loftus, E. F. (1983). *Mind at play: The psychology of video games*. New York, NY: Basic Books.

Lorenz, K. (1971). *Studies in animal and human behavior*. Cambridge, MA: Harvard University Press.

Lorenz, K. (1981). *The foundations of ethology*. New York, NY: Springer Verlag.

Loucks, S. F., & Zacchei, D. A. (1983). Applying our findings to today's innovations. *Educational Leadership, 41*(3) 28-31.

Loughary, J. W. (1966). *Man-machine systems in education*. New York, NY: Harper & Row, Publishers.

Lumsdaine, A. A. (1959). Teaching machines and self-instructional materials. *Audio-Visual Communication Review, 7*, 163-181.

Lumsdaine, A. A., & Glaser, R. (Eds.). (1960). *Teaching machines and programmed learning: A source book.* Washington, DC: National Education Association of the United States.

Lyman, E. R. (1978). *PLATO® highlights.* Urbana, IL: Computer-based Education Research Laboratory, University of Illinois.

Lysaught, J. P. (1962). Programed learning and teaching machines in industrial training. In S. Margulies & L. Eigen (Eds.) *Applied programed instruction.* New York, NY: John Wiley and Sons, Inc.

Maass, E. (1858). *Commentariorum in Aratum reliquiæ* [Notes on the surviving works of Aratus]. Berlin: Weidmann (reprinted, 1958).

Mager, R. F. (1959). Preliminary studies in automated teaching. *IRE Transactions on Education, E-2*(3) 104-107.

Mandell, C. J., & Mandell, S. L. (1989). *Computers in education today.* St. Paul, MN: West Publishing Company.

Mann, D. (Ed.). (1978). *Making change happen?* New York, NY: Teachers College Press.

Margulies, S., & Eigen, L. D. (1962). *Applied programed instruction.* New York, NY: John Wiley and Sons, Inc.

Marsh, Z. A. (1956). An audio-visual climate. *Audio-Visual Instruction, 1*, 178-179.

Marshall, K. (1979). Speak & Spell: A classroom hit. *Learning, 8*(3) 80.

Marrou, H. I. (1956). *A history of education in antiquity* (translated by G. Lamb). New York, NY: Sheed and Ward.

Mattas, L. L. (1986). *Only the best: The discriminating software guide for preschool — grade 12.* Carmichael, CA: Education News Service.

McCann, P. & Young, F. A. (1982). *Samuel Wilderspin and the infant school movement.* London: Croom Helm.

McClusky, F. D. (1924). Comparisons of different methods of visual instruction. In F. N. Freeman (Ed.) *Visual education: A comparative study of motion pictures and other methods of instruction.* Chicago: University of Chicago Press.

McIntyre, J. W. (1980). Computer-aided instruction as part of an undergraduate programme in anæsthesia. *Canadian Anæsthesiological Society Journal, 27*(1) 68-73.

McKenzie, T. (1974). *It's time to remember, 1874-1974: A hundred years of progress, Tremaine - Hunterville area.* Steinbach, Manitoba: Tremaine Activity Group.

McLaughlin, M. W. (1978). Implementation as mutual adaptation: Change in classroom organization. In D. Mann (Ed.) *Making change happen?* New York, NY: Teachers College Press.

Mead, L. C. (1949). Psychology at the special devices center, office of naval research. *American Psychologist, 4,* 97-103.

Means, B., & Gott, S. P. (1988). Cognitive task analysis as a basis for tutor development: Articulating abstract knowledge representations. In J. Psotka, L. Massey, & S. Mutter (Eds.) *Intelligent tutoring systems: Lessons learned.* Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Mellan, I. (1936). Teaching and educational inventions. *Journal of Experimental Education,* 4(2) 291-300.

Meltz, B. (1991, April 21). Nintendo time: Exciting tool for teaching or high-tech waste of time? *The Edmonton Journal,* p. F4.

Menninger, K. (1979). *Zahlwort und ziffer: Eine kulturgeschicte der zahl* [Numeral and figure: A cultural history of numbers]. Göttingen: Vandenhoeck & Ruprecht.

Merrill, M. D. (1988). Applying component display theory to the design of courseware. In D. H. Jonassen (Ed.) *Instructional designs for microcomputer courseware.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Merrill, M. D., Schneider, E. W., & Fletcher, K. A. (1980). *TICCIT.* Englewood Cliffs, NJ: Educational Technology Publications.

Miles, R. (1975). Computers in simulators in the armed services. In R. Hooper & I. Toye (Eds.) *Computer assisted learning in the United Kingdom.* London: CET National Development Programme in Computer Assisted Learning.

Miller, H. (1988). *An administrator's manual for the use of microcomputers in the schools.* Englewood Cliffs, NJ: Prentice-Hall.

Miller, M. (Ed.). (1987). *Microcomputers in education conference: Who's in charge?* Rockville, MD: Computer Science Press.

Miller, N. E., & Dollard, J. (1941). *Social learning and imitation.* New Haven, CT: Yale University Press.

Minsky, M. (1985). *The society of mind.* New York, NY: Simon & Schuster Inc.

Molnar, A. R. (1979). The next crisis in American education: Computer literacy. *EDUCOM Bulletin,* Spring, 2-6.

Montessori, M. (1912). *The Montessori method.* New York, NY: Frederick A. Stokes Company.

Moore, O. K. (1962). *The automated responsive environment.* New Haven, CT: Yale University.

Moore, O. K. (1964). Autotelic responsive environments and exceptional children. In *Special children in century 21.* Seattle, WA: Special Child Publications.

Moore, O. K. (1965). From tools to interactional machines. In *New approaches to individualizing instruction.* Princeton, NJ: Educational Testing Service.

Moore, O. K. (1980). About talking typewriters, folk models, and discontinuities: A progress report on twenty years of research, development, and application. *Educational Technology, 20*(2) 15-27.

Morgan, J. E. (1930). Radio and education, in M. Codell (Ed.), *Radio and its future.* New York, NY: Harper & Brothers Publishers.

Morgan, S. A. (1913). *The Montessori method, an exposition and criticism: Ontario Department of Education Bulletin no. 1.* Toronto: L. K. Cameron.

Morrill, C. S. (1961). Teaching machines: A review. *Psychological Bulletin, 58*(5) 363-375.

Mowrer, O. H., & Mowrer, W. M. (1938). Enuresis—a method for its study and treatment. *The American Journal of Orthopsychiatry, 8,* 436-459.

Mueller, R. J. (1987). Two practical problems. *Phi Delta Kappan, 68,* 413-414.

Muller, L. A. (1967). Industry's role in education. *Educational Technology, 7*(10) 8-12.

Munson, H. (1991). Readin', writin', and railroadin'. *Model Railroader, 58*(12) 105-107.

Murray-Lasso, M. A. (1987). The use of microcomputers for education and training in Latin America. In *Microcomputer applications in education and training for developing countries.* Boulder, CO: Westview Press.

Myers, K. (1913). Séguin's principles of education as related to the Montessori method. *Journal of Education, 77,* 538-541.

National Council of Teachers of Mathematics. (1973). *Instructional aids in mathematics: Thirty-fourth yearbook.* Washington, DC: Author.

National Schools. (1951). Learn radio, television, electronics by shop method home training: advertisement. *Radio & Television News,* February, p. 37.

Naylor, T. H., Balintfy, J. L., Burdick, D. S., & Chu, K. (1966). *Computer simulation techniques.* New York, NY: John Wiley & Sons, Inc.

Needham, J., & Ling, W. (1959). *Science and civilization in China: Volume III, mathematics and the sciences of the heavens and the earth.* Cambridge: Cambridge University Press.

Neumann, R. (1983). Pre-programmed learning aids: An alternative worth considering. *Electronic Learning,* 2(4) 66-68.

New Application for General Electric Device. (1965). *Teaching Aids News, 5*(7) 14.

Niemiec, R. P., & Walberg, H. J. (1989). From teaching machines to microcomputers: Some milestones in the history of computer-based instruction. *Journal of Research on Computing in Education, 21*(3) 263-276.

Noel, F. W. (1961). Film-Prima donna of the audiovisual world. *Audiovisual Instruction, 6,* 8-11.

North, J. D. (1966). Opus quorundam rotarum mirabilium. *Physis, 8,* 337-371.

North, S. (1979). The Terrapin turtle. *Creative Computing, 5*(3) 105-106.

Odor, P. (1982). Microcomputers and disabled people. *International Journal of Man-Machine Studies, 17,* 51-58.

Officers learn skills to run new frigates. (1988, October 12). *The Edmonton Journal,* p. E10.

Ohles, J. F. (1985). The microcomputer: Don't love it to death. *Technical Horizons in Education Journal, 13*(1) 49-53.

Olson, J. (1988). *Schoolworlds/Microworlds: Computers and the culture of the classroom.* Oxford: Pergamon Press.

Ordahl, L. E., & Ordahl, G. (1915). Qualitative differences between levels of intelligence in feeble-minded children. *Journal of Psycho-Asthenics, Monograph Supplements, 1*(2).

Orme, N. (1973). *English schools in the middle ages.* London: Methuen & Co. Ltd.

Ost, L. (1981). *Seven Persons: One hundred and sixty acres and a dream.* Medicine Hat: Seven Persons Historical Society.

Outdoor innovations galore at boat & sportsmen's show. (1990, March 13). *The Edmonton Journal*, p. D9

Owen, S. (1978). Qwerty is obsolete. *Interface age, 3*(1) 56-59.

Owen, S. G., Hall, R., & Waller, I. B. (1964). Use of a teaching machine in medical education; Preliminary experience with a programme in electrocardiography. *The Postgraduate Medical Journal, 40*, 59-65.

Pagliaro, L. A. (1983). The history and development of CAI: 1926-1981, an overview. *The Alberta Journal of Educational Research, 29*(1) 75-84.

Papert, S. (1980a). *Mindstorms: Children, computers, and powerful ideas.* New York, NY: Basic Books, Inc.

Papert, S. (1980b). New cultures from new technologies. *Byte, 5*(9) 230-240.

Papert, S. (1984). New theories for new learning. *School Psychology Review, 13*(4) 422-428.

Parrish, L. (1969). *Space-flight simulation technology.* Indianapolis, IA: Howard W. Sams & Co., Inc.

Pask, G. (1958). Electronic keyboard teaching machines. In A. A. Lumsdaine and R. Glaser (Eds.) (1960). *Teaching machines and programmed learning, a source book.* Washington, DC: National Education Association of the United States.

Pask, G. (1959). The teaching machine. *The Overseas Engineer*, February, 231-232.

Pask, G. (1960). Adaptive teaching with adaptive machines. In A. A. Lumsdaine and R. Glaser (Eds.) *Teaching machines and programmed learning, a source book.* Washington, DC: National Education Association of the United States.

Pask, G. (1966). Men, machines and the control of learning. *Educational Technology, 6*(22) 1-12.

Pask, G. (1975). *The cybernetics of human learning and performance: A guide to theory and research.* London: Hutchinson & Co (Publishers) Ltd.

Pask, G. (1982). SAKI: Twenty-five years of adaptive training into the microprocessor era. *International Journal of Man-Machine Studies, 17,* 69-74.

Pea, R. D. (1984). *Integrating human and computer intelligence.* (Technical Report No. 32). Washington, D.C.: United States Department of Education. (ERIC Document Reproduction Service No. IR 011 682)

Penso, R. A. (1992, July). Dvorak's class act [letter to the editor]. *MacUser, 8*(7) 16.

Pestalozzi, J. H. (1898). *How Gertrude teaches her children* (translated by L. E. Holland & F. C. Turner). Syracuse, NY: C. W. Bardeen.

Peterson, J. C. (1930). A new device for use in teaching, testing and research in learning. *Transactions of the Kansas Academy of Science, 33,* 41-47.

Peterson, J. C. (1931). The value of guidance in reading for information. *Transactions of the Kansas Academy of Science, 34,* in A. A. Lumsdaine and R. Glaser (Eds.) (1960). *Teaching machines and programmed learning, a source book.* Washington, DC: National Education Association of the United States.

Peterson, R. C., & Thurstone, L. L. (1932). The effects of a motion picture film on children's attitudes toward Germans. *The Journal of Educational Psychology, 23*(4) 241-246.

Petruk, M. W. (1986). *Microcomputers in Alberta schools – 1986.* Edmonton: Alberta Education Media Technology Branch.

Philco-Ford Displays Computer Assisted Instruction. (1968). *Educational Technology, 8*(6) 18.

Philip, J. H. (1987). Gas Man® — An example of goal oriented computer-assisted teaching which results in learning. *International Journal of Clinical Monitoring and Computing, 3*(3) 165-173.

Phillips, E. (1976). Development of keyboard skills teaching machines. In Clarke, J., & Leedham, J. (Eds.) *Aspects of educational technology, volume X: Educational technology for individualised learning*. London: Kogan Page Limited.

Piagét, J. (1966). *Psychology of intelligence*. Totowa, NJ: Littlefield, Adams.

Piagét, J. (1977). *Science of education and the psychology of the child.* Harmondsworth, Middlesex: Penguin Books.

Pinchak, A. C., Hancock, D. E., Hagen, J. F., & Hall, F. B. (1987) The chest wall dynamics of CPR: What works. *Soma: Engineering for the human body, 2*(1) 6-17.

Platt, H. (1965). Teaching machines working well with retarded students. *The Rehabilitation Record, 6*(5) 25-27.

Platt, H., Cifelli, J., & Knaus, W. (1966). *Automation in the training of the mentally retarded: Final report VRA 993-P-63.* Devon, PA.: The Devereux Foundation.

Ploch, M. (1986). Computers in the schools: Can they make the grade? *High Technology, 6*(9) 44-50.

Plugin, V. G. (1970). Programmed instruction and teaching machines in the USSR. *Soviet Cybernetics Review,* June, 17-28.

Pollio, H. W. (1974). *The psychology of symbolic activity.* Reading MA: Addison-Wesley Publishing Company.

Polony, L. J. (1965). Programmed instruction and automated education for hospital and other medical personnel. *Hospital Progress, 46*, 83-87, 120.

Porter, D. (1957). A critical review of a portion of the literature on teaching devices. *Harvard Educational Review, 27*(2) 126-147.

Poulle, E. (1963). *Un constructeur d'instruments astronomiques au XV^e^ siécle, Jean Fusoris* [A builder of astronomical instruments of the sixteenth century, Jean Fusoris]. Paris: Librairie Honoré Champion, Éditeur.

Pressey, S. L. (1921). The influence of color upon mental and motor efficiency. *American Journal of Psychology, 32*, 326-356.

Pressey, S. L. (1926). A simple apparatus which gives tests and scores-and teaches. *School and Society, 23*(586) 373-376.

Pressey, S. L. (1927). A machine for automatic teaching of drill material. *School and Society, 25*(645) 549-552.

Pressey, S. L. (1932). A third and forth contribution toward the coming "industrial revolution" in education. *School and Society, 36*(934) 668-672.

Pressey, S. L. (1946). Further attempts to develop a "mechanical teacher". *American Psychologist, 1*, 262.

Pressey, S. L. (1947). Educational acceleration. *Educational Research Bulletin, 26*, 219-220.

Pressey, S. L. (1950). Development and appraisal of devices providing immediate automatic scoring of objective tests and concomitant self-instruction. *The Journal of Psychology, 29*, 417-447.

Pressey, S. L. (1962). Basic unresolved teaching-machine problems. *Theory Into Practice*, 1, 31-37.

Pressey, S. L. (1963). Teaching machine (and learning theory) crisis. *Journal of Applied Psychology, 47*(1) 1-6.

Pressey, S. L. (1964a). Autoinstruction: Perspectives, problems, potentials. In E. R. Hilgard (Ed.) *Theories of learning and instruction: The sixty-third yearbook of the national society for the study of education, part I.* Chicago, IL: National Society for the Study of Education.

Pressey, S. L. (1964b). A puncture of the huge "programing" boom? *Teachers College Record, 65*, 413-418.

Pressey, S. L. (1967). Autobiography. In E. G. Boring & G. Lindzey (Eds.) *A history of psychology in autobiography: Volume V.* New York, NY: Appleton-Century-Crofts.

Pressey, S. L., & Kinzer, J. R. (1964). Auto-elucidation without programing! *Psychology in the schools, 1*, 359-365.

Price, D. J. de S. (1954). A collection of armillary spheres and other antique scientific instruments. *Annals of Science, 10*, 172-187.

Price, D. J. de S. (1964). Automata and the origins of mechanism and mechanistic philosophy. *Technology and Culture, 5*(1) 9-23.

Price, D. J. de S. (1974). Gears from the Greeks: The Antikythera mechanism - a calendar computer from ca. 80 B.C. *Transactions of the American Philosophical Society, 64*(7).

Price, D. J. de S., & Wilson, R. M. (1955). *The equatorie of the planets.* Cambridge: Cambridge University Press.

Psotka, J., Massey, L. D., & Mutter, S. A. (1988). Knowledge acquisition. In J. Psotka, L. Massey, & S. Mutter (Eds.) *Intelligent tutoring systems: Lessons learned.* Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Pullan, J. M. (1968). *The history of the abacus.* New York, NY: Frederick A. Praeger, Publisher.

Quackenbush, J. (1961). How effective are the new auto-instructional materials and devices? *IRE Transactions on Education, E-4*(4) 144-151.

Quintilian. *Declamationes.* In M. Winterbottom (Ed.) *The minor declamations ascribed to Quintilian.* Berlin: Walter de Gruyter.

Quintilian. *Institutio oratoria, I* (translation by H. E. Butler, 1921). London: William Heinemann.

Quintilian. *Institutio oratoria, IV* (translation by H. E. Butler, 1922). London: William Heinemann.

Rademacker, H. (1967). Programmed instruction in Germany. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology.* London: Methuen & Co. Ltd.

Ragsdale, R. G. (1988). *Permissible computing in education: Values, assumptions, and needs.* New York, NY: Praeger.

Rahmlow, H. F., Fratini, R. C., & Ghesquiere, J. R. (1980). *PLATO.* Englewood Cliffs, NJ: Educational Technology Publications.

Randell, B. (1980). The COLOSSUS. In N. Metropolis, J. Howlett, & G-C. Rota, (Eds.) *A history of computing in the twentieth century.* New York, NY: Academic Press.

Rath, G. J. (1967). The development of computer-assisted instruction. *IEEE Transactions on Human Factors in Electronics, HFE-8*(2).

Rath, G. J., Anderson, N. S., & Brainerd, R. C. (1959). The IBM research center teaching machine project. In E. Galanter (Ed.) *Automatic teaching: The state of the art.* New York, NY: John Wiley & Sons, Inc.

RCA Instructional Systems. (1967a). *Instructional 70 system general information.* Palo Alto, CA: Author.

RCA Instructional Systems. (1967b). *User's guide to instructional language-1*. Palo Alto, CA: Author.

RCA Instructional Systems. (1968a). *Instructional 70 system summary*. Palo Alto, CA: Author.

RCA Instructional Systems. (1968b). *Instructional 70 teacher's guide*. Palo Alto, CA: Author.

RCA Photophone, Inc. (1930). Sight and sound in education: Advertisement. *School Board Journal, 81*(5) 81.

Reid, R. L. (1964). Linear programming and learning. In K. Austwick (Ed.) *Teaching machines and programming*. New York, NY: The Macmillan Company.

Reid-Green, K. S. (1979a). History of computers: The IBM 650. *Byte, 4*(3) 238-240.

Reid-Green, K. S. (1979b). History of computers: The IBM 704. *Byte, 4*(1) 190-192.

Reigeluth, C. M. (1979). TICCIT to the future: Advances in instructional theory for CAI. *Journal of Computer-Based Education, 6*(2) 40-46.

Reiser, R. A. (1987). Instructional technology: A history. In R. Gagné (Ed.) *Instructional technology: Foundations*. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Richardson, L. J. (1916). Digital reckoning among the ancients. *American Mathematical Monthly, 23*(1) 7-13.

Richer. (999). Historiarum in libri quatuor. In Pertz (Ed.) *Monumenta Germanica historiae, Patrologiae Latinae, tomus 138*, ca. 1875. Turnholti, Belgium: Brepols Editores.

Ricker, M. B. (1938). Individualized instruction. *The A.T.A. Magazine, 19*(1) 19-21.

Ringham, G. B., & Cutler, A. E. (1954). Flight simulators. *The Journal of the Royal Aeronautical Society, 58*(518) 153-170.

Roberts, L. (1943). *Canada's war in the air*. Montréal: A. M. Beatty.

Robinson, E. S. (1927). The "similarity" factor in retroaction. *American Journal of Psychology, 39*, 297-312.

Rogers, C. R. (1982). Nuclear war: A personal response. *APA Monitor 13*(August) 6.

Romaniuk, E. W. (1970). *A versatile authoring language for teachers.* Unpublished Ph.D. dissertation, Department of Educational Psychology, University of Alberta, Edmonton.

Rosencrantz, D. M., & Blair, W. C. (1969). The simulation of deep ocean search missions. *Photo-optical techniques in simulators: S.P.I.E. seminar proceedings, Volume 17.* ?: Society of Photo-Optical Instrumentation Engineers.

Rossall, R. E. (1974). *Computer-assisted learning in an undergraduate M.D. cardiology program.* Edmonton: Division of Educational Research Services, University of Alberta.

Rostunov, T. И. (1970). *Программировнное обучение и обучающие машины* [Programmed instruction and teaching machines]. Moscow.

Roth, R. H. (1963). Student reactions to programed learning. *Phi Delta Kappan, 44,* 278-281.

Rousseau, J. J. (1948). *Émile.* London: J. M. Dent & Sons Ltd.

Rutherford, G. (Ed.). (1961). *Programed learning and its future in Canada.* Ottawa: Canadian Teachers' Federation.

Saettler, P. (1968). *A history of instructional technology.* New York, NY: McGraw-Hill Book Company.

Saettler, P. (1979). *An assessment of the current status of educational technology.* Syracuse, NY: ERIC Clearninghouse on Information Resources.

Sammet, J. E. (1969). *Programming languages: History and fundamentals.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Sandoval, V. A., Dale, R. A., Hendricson, W. D., & Alexander, J. B. (1987). A comparison of four simulation and instructional methods for endodontic review. *Journal of Dental Education, 51,* 532-538.

Saskatchewan Department of Education. (1975). *Annual report 1974-75.* Regina: Author.

Savage-Smith, E., & Smith, M. B. (1980). *Islamic geomancy and a thirteenth-century divinatory device.* Malibu, CA: Undena Publications.

Schlebecker, J. T. (1977). Farmers and bureaucrats: Reflections on technological innovation in agriculture. *Agricultural History, 51,* 641-655.

Schmidt, H. W. (1930). Blackboards: Their heighth and width. *School Board Journal*, *81*(3), 43-45.

Schure, A. (1963). An automated teaching system. *Teaching Aids News*, *3*(21) 6-11.

Schure, A. (1965). Educational escalation through systems analysis: Project ULTRA at New York Institute of Technology. *Audiovisual Instruction*, *10*, 371-376.

Seireg, A. A. (1987). Meeting the manikin with the death mask. *Soma: Engineering for the human body*, 2(1) 12-13.

Selsnick, T. (1988). Bunk! Computer myths we can live without. In J. Rich (Ed.) *Innovations in education: Reformers and their critics*. Boston: Allyn and Bacon, Inc.

Silberman, H. F., & Carter, L. F. (1965). The systems approach, technology, and the school. In *New approaches to individualizing instruction*. Princeton, NJ: Educational Testing Service.

Simpkins, K. H., & Emms, E. T. (1953). Flight simulators. *Electronic Engineering*, *25*(305) 270-273.

Simulation in training. (1966). *Educational Technology*, *6*(17) 21.

Skinner, B. F. (1953). *Science and human behavior*. New York, NY: The Macmillan Company.

Skinner, B. F. (1954). The science of learning and the art of teaching. *The Harvard Educational Review*, *24*, 86-97.

Skinner, B. F. (1958). Teaching machines. *Science*, *128*(3330) 969-977.

Skinner, B. F. (1961a). Teaching machines. *Scientific American*, *205*(5) 91-102.

Skinner, B. F. (1961b). Why we need teaching machines. *Harvard Educational Review*, *31*(4) 377-398.

Skinner, B. F. (1965). Reflections on a decade of teaching machines. In R. Glaser (Ed.) *Teaching machines and programmed learning, II: Data and directions*. Washington, DC: National Education Association of the United States.

Skinner, B. F. (1968). *The technology of teaching*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Skinner, B. F. (1971). *Beyond freedom and dignity*. Toronto: Bantam Books.

Skinner, B. F. (1976). *Particulars of my life*. New York, NY: Alfred A. Knopf.

Skinner, B. F. (1979). *The shaping of a behaviorist: Part two of an autobiography*. New York, NY: Alfred A. Knopf.

Skinner, B. F. (1983). *A matter of consequences: Part three of an autobiography*. New York, NY: Alfred A. Knopf.

Skinner, B. F. (1984). The shame of American education. *American Psychologist, 39,* 947-954.

Skinner, B. F. (1986). Programmed instruction revisited. *Kappan, 68*(2) 103-110.

Slack, C. W. (1967). The truth about computerized instruction. *Educational Technology, 7*(19) 8-14.

Sleep-Learning Research Association. (1962). The amazing electronic educator: advertisement. *Audiovisual Instruction, 7,* 46.

Smalley, B. (1960). *English friars and antiquity in the early fourteenth century*. New York, NY: Barnes & Noble, Inc.

Smellie, W. R. (1876). *A treatise on the theory and practice of midwifery, 2 vols*. London: The New Sydenham Society.

Smith, D. E. (1958). *History of mathematics: Volume II, special topics of elementary mathematics*. New York, NY: Dover Publications, Inc.

Smith, S. G., & Ghesquiere, J. R. (1974). Computer-based teaching of organic chemistry. In J. S. Mattson, H. B. Mark, Jr., and H. C. MacDonald, Jr. (Eds.) *Computer-assisted instruction in chemistry (in two parts): Part B: Applications*. New York, NY: Marcel Decker, Inc.

Solartron Simulation. (1985). *Shipborne radar trainer*. Farnborough, United Kingdom: Solartron Schlumberger.

Soles, S. (1963). Educational quackery external to our schools: What is a professional response? *Phi Delta Kappan, 44,* 299-301.

Sorestad, G. A. (Ed.). (1963). *Programed instruction: Report of the western conference of teacher organizations*. Saskatoon: Western Conference of Teacher Organizations.

Speert, H. (1973). *Iconographica gyniatrica: A pictorial history of gynecology and obstetrics*. Philadelphia, PA: F. A. Davis.

Spencer, H. R. (1978). *The history of British midwifery from 1650 to 1800*. New York, NY: AMS Press.

Spencer, K. (1988). *The psychology of educational technology and instructional media*. London: Routledge.

Spivack, A. P. & Miller, D. K. (1967). The arrhythmia trainer. *Journal of the American Medial Association, 202,* 151-153.

Stahl, S. M., & Hennes, J. D. (1973). Biostatics: An experiment with self-learning in the health sciences. *Journal of Medical Education, 48*(3) 271-275.

Stavert, G. S. (1967). Programmed instruction in the Royal Naval electrical school. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology*. London: Methuen & Co. Ltd.

Stecklow, S. (1990, June 12). Meet the new teacher — Super Mario. *The Edmonton Journal*, p. C7.

Steg, D. R., & Schenk, R. (1977). Intervention through technology: The "talking typewriter" revisited. *Educational Technology, 17*(10) 45-47.

Stephens, A. L. (1953). Certain special factors involved in the law of effect. *Abstracts of Doctoral Dissertations, 64*, 505-511.

Stepp, R. E. (1966). Programming 8mm films to teach speechreading to deaf children. *Audiovisual Instruction, 11*, 177-181.

Stetten, K. J. (1971). The technology of small, local facilities for instructional use. In R. E. Levien (Ed.) *Computers in instruction: Their future for higher education*. Santa Monica, CA: Rand Corporation.

Stevens, C. B., Enzor, M., Phillips, T., & Small, P. A. (1973). An evaluation of self-instructional package on amino acid and protein chemistry. *Journal of Medical Education, 48*(3) 276-279.

Stevenson, E. L. (1921). *Terrestrial and celestial globes: Their history and construction including a consideration of their value as aids in the study of geography and astronomy* (Vols. I & II). New Haven, CT: Yale University Press.

Stewart, W. A. C., & McCann, W. P. (1967). *The educational innovators 1750-1880.* London: Macmillan.

Stewart, W. A. C. (1968). *The educational innovators volume II: Progressive schools 1881-1967.* London: Macmillan.

Stolurow, L. M. (1961). *Teaching by machine.* Washington, DC: U.S. Department of Health, Education, and Welfare.

Stolurow, L. M. (1963). Let's be informed on programed instruction. *Phi Delta Kappan, 44,* 255-257.

Stolurow, L. M. (1967a). A computer assisted instructional system in theory and research. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology.* London: Methuen & Co. Ltd.

Stolurow, L. M. (1967b). Computer-based instruction: Psychological aspects and systems conception of instruction. *Journal of Educational Data Processing, 4*(4) 193-215.

Stolurow, L. M., & Davis, D. (1965). Teaching machines and computer-based systems. In R. Glaser (Ed.) *Teaching machines and programmed learning, II: Data and directions.* Washington, DC: National Education Association of the United States.

Stukat, K. G. (1964). Construction and field testing of a grammar program. *Programmed learning, 2*(1) 14-19.

Sturwold, V. G. (1961). Sources of self-instructional devices. *Audiovisual Instruction, 6,* 144-145.

Suetake, K. (1972). Review of research activities on simple and unique teaching machines in Japan. *IEEE Transactions on Education, E-15*(4) 220-226.

Suppes, P. (1966). The uses of computers in education. *Scientific American, 215*(3) 207-220.

Suppes, P. (1969). Computer technology and the future of education. In R. C Atkinson & H. A. Wilson (Eds.) *Computer-assisted instruction: A book of readings.* New York, NY: Academic Press.

Suppes, P., & Jerman, M. (1969). Computer assisted instruction at Stanford. *Educational Technology, 9*(4) 22-24.

Suppes, P., & Macken, E. (1978). The historical path from research and development to operational use of CAI. *Educational Technology, 18*(4) 9-12.

Tait, C. (1988, October 27). Simulator for disabled drivers. *The Edmonton Journal*, p. E5.

Tanner, G. E., Angers, D. G., Van Ess, D. M., & Ward, C. A. (1986). ANSIM: An anesthesia simulator for the IBM PC. *Computer Methods and Programs in Biomedicine, 23*(2) 237-242.

Taylor, F. V. (1947). Psychology at the naval research laboratory. *American Psychologist, 2,* 87-92.

Taylor, J. L., & Walford, R. (1978). *Learning and the simulation game.* Milton Keynes: Open University Press.

Teaching Technology Corporation. (1967). A magnetic card reader which costs less!: advertisement. *Audiovisual Instruction,12*, 968.

Terrell, C. D., & Linyard, O. (1982). Evaluation of electronic learning aids: Texas Instruments' "Speak Spell". *International Journal of Man-Machine Studies, 17,* 59-67.

Texas Instruments. (1990). *Gifts to stimulate and educate.*

The computer and the medical student. (1972). *Data Processor*, 2(3) 16-20.

Thomson, R. B. (1978). *Jordanus de Nemore and the mathematics of astrolabes: De plana spera.* Toronto: Pontifical Institute of Mediaeval Studies.

Thorndike, E. L. (1906). *The principles of teaching based on psychology.* New York, NY: A. G. Seiler.

Thorndike, E. L. (1912). *Education: A first book.* New York, NY: The Macmillan Company (Reprinted by Arno Press Inc., 1973).

Thorndike, E. L. (1913a). *Educational psychology, volume I: The original nature of man.* New York: Teachers College, Columbia University.

Thorndike, E. L. (1913b). *Educational psychology, volume II: The psychology of learning.* New York: Teachers College, Columbia University.

Thorndike, E. L. (1914). *Educational psychology, volume III: Mental work and fatigue and individual differences and their causes.* New York: Teachers College, Columbia University.

Thorndike, E. L. (1917). *The Thorndike arithmetics: Book three*. New York, NY: Rand McNally & Company.

Thorndike, E. L. (1931). *Human learning*. New York, NY: The Century Co.

Thorndike, E. L. (1932). *Fundamentals of learning*. New York, NY: Teachers College, Columbia University.

Thorndike, L. (1949). *The sphere of Sacrobosco and its commentators*. Chicago, IL: University of Chicago Press.

Tikonov, И. И. (1970). *Программирование и технические средства в учебном процессе* [Programming and technical methods in the instructional process]. Moscow.

Tolman, E. C. (1958). *Behavior and psychological man: Essays in motivation and learning*. Berkeley, CA: University of California Press.

Tolman, E. C., & Honzik, C. H. (1930). Introduction and removal of reward, and maze performance in rats. *University of California Publications in Psychology, 4,* 257-275.

Treichler, D. G. (1967). Are you missing the boat in training aids? *Film and AV Communication, 1*, 14-16.

Trotter, H., Jr. (1965). Total communications in education. *Teaching Aids News, 5*(13) 1-7.

Tucker, M. (1985). From drill sergeant to intellectual assistant: Computers in the schools. *Carnegie Quarterly, 30*(3&4) 1-7.

Tucker, M. S. (1986). Computers in the schools: What revolution? *Journal of Communication, 36*(4) 12-23.

Tuer, A. W. (1896). *History of the horn-book: Volume I & II*. London: Leadenhall Press.

Umans, S. (1969). Computer-assisted instruction New York City. In R. C Atkinson & H. A. Wilson (Eds.) *Computer-assisted instruction: A book of readings*. New York, NY: Academic Press.

United States Office of Technological Assessment. (1988). *Power on! New tools for teaching and learning*. Washington, DC: Author.

Unwin, D., & Leedham, J. (1967). Educational technology in 1966. In D. Unwin & J. Leedham (Eds.) *Aspects of educational technology*. London: Methuen & Co. Ltd.

U. S. Industries introduces device for self-testing and review. (1963). *Teaching Aids News, 3*(1) 5.

Uttal, W. R. (1962). On conversational interaction. In J. E. Coulson (Ed.) *Programmed learning and computer-based instruction: Proceedings of the conference on application of digital computers to automated instruction.* New York, NY: John Wiley and Sons, Inc.

Uttal, W. R. (1966). Academic responsibility and corporate influence. *Educational Technology, 6*(23) 1-12.

Valerius Maximus. *Facta et dicta memorabilia* [Memorable acts and sayings]. (compiled by C. Kempf, 1854, reprinted 1976). Hildesheim: Georg Olms Verlag.

Van Valkenburgh, Nooger & Neville. (1965). Simple! Trainer-tester advertisement. *Audiovisual Instruction, 10,* 174.

Vargas, J. S. (1986). Instruction design flaws in computer-assisted instruction. *Phi Delta Kappan, 67*(10) 738-744.

Vegetius. *Epitoma rei militaris* (compiled by C. Lang, 1885, reprinted 1967). Stuttgart: B. G. Tuebner.

Victor Talking Machine Co. (1921). The Victrola serves indoors, outdoors, winter or summer, rain or shine, in work or in play: advertisement. *School Board Journal, 63*(5) 59.

Virtual Prototypes, Inc. (1988a). *VAPS/flight simulator.* ?: Author.

Virtual Prototypes, Inc. (1988b). *Solutions: VPI aerospace simulation.* ?: Author.

Vlcek, C. (1966). Classroom simulation in teacher education. *Audiovisual Instruction, 11,* 86-90.

V-M Corporation. (1960). Now! Teaching and Self, "Add+A+Track": advertisement. *Audiovisual Instruction, 5,* 147.

Wagenaar, W. A. (1975). Supertankers: Simulators for the study of steering. *American Psychologist, 30,* 440-444.

Wager, W., & Gagné, R. M. (1988). Designing computer-aided instruction. In D. H. Jonassen (Ed.) *Instructional designs for microcomputer courseware*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Wagner, F. V. (1976). Is decentralization inevitable? *Datamation, 22*, 86-97.

Wallis, D., & Wicks, R. P. (1964). The Royal Navy study. *Programmed learning, 1*(1) 31-47.

Warner, H. R., & Budkin, A. (1968). A "link trainer" for the coronary care unit. *Computers and Biomedical Research*, 2, 135-144.

Watson, J. B. (1928). *The ways of behaviorism.* New York, NY: Harper & Brothers Publishers.

Watson, J. B. (1930). *Behaviorism.* Chicago, IL: University of Chicago Press.

Watson, J. B., & Rayner, R. (1920). Conditioned emotional reactions. *Journal of Experimental Psychology, 3*, 1-14.

Watt, D. H. (1979). A comparison of the problem solving styles of two students learning LOGO: A computer language for children. *Creative Computing, 5*(12) 86-90.

Watts, M. L. (1954). Your classroom radio and the curriculum, in *Alberta school broadcasts teacher guide, 1954-55*. Edmonton: Alberta Department of Education.

Weimer, P. K. (1958). A proposed 'automatic' teaching device. *IRE Transactions on Education, E-1*(2) 51-53.

Wenger, E. (1987). *Artificial intelligence and tutoring systems: Computational and cognitive approaches to the communication of knowledge*. Los Altos, CA: Morgan Kaufmann Publishers, Inc.

White, K. D. (1984). *Greek and Roman technology.* London: Thames and Hudson Ltd.

White, M. A. (Ed.). (1983). *The future of electronic learning*. Hillsdale, NJ: Lawrence Erlbaum Associates.

WICAT Systems (1989). Advertisement. *The Electronic School*, September, A4-A5.

WICAT Systems (n.d.). *Training systems*. Orem, UT: Author.

WICAT Systems (n.d.). *WISE: WICAT's interactive system for education*. Orem, UT: Author.

WICAT Systems (n.d.). *WIT: WICAT interactive terminal.* Orem, UT: Author.

Wickens, C. D., Haskell, I., & Harte, K. (1989). Ergonomic design for perspective flight-path displays. *IEEE Control Systems, 9*(4) 3-8.

Wiener, N. (1948). *Cybernetics: Or control and communication in the animal and the machine.* New York: John Wiley & Sons, Inc.

Wilderspin, S. (1825). *Infant education.* London: ?

Williams, M. R. (1985). *A history of computing technology.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Williams, T. G., & Frye, C. H. (1968). An instructional application of computer games. *Educational Technology, 8*(11) 5-8.

Winter, H. J. J. (1956). Muslim mechanics and mechanical appliances. *Endeavour, 15,* 25-28.

Wirt, J. G. (1978). Implementing diagnostic/prescriptive reading innovations. In D. Mann (Ed.) *Making change happen?* New York: Teachers College Press.

Witty, P. A., & Goldberg, S. (1944). The use of visual aids in special training units in the army. *Journal of Educational Psychology, 35,* 82-90.

Wohlwill, J. F. (1962). The teaching machine: Psychology's new hobbyhorse. *Teachers College Record, 64*(2) 139-146.

Wollard, K. (1988). Computers in the public schools: Is the revolution faltering? The Institute, 12(11) 1.

Wolman, R. (1986). Survey of authoring systems. In, *The 1986 guide to computer-based training: Systems and courseware.* Boston, MA: Weingarten Publications, Inc.

Wood, B. D., & Freeman, F. N. (1929). *Motion pictures in the classroom.* Boston: Houghton Mifflin Co.

Wood, W. W. Jr. (1952). The modern flight simulator. *Electrical Engineering, 71,* 1124-1129.

Woolley, R. D. (1979). Microcomputers and videodiscs: New dimensions for computer-based education. *Interface Age, 4*(12) 78-82.

Wynne, G. (1986). ABC of resuscitation. *British Medical Journal, 293*(6538) 30-32.

Young, E. (1953). *One of our submarines.* London: Penguin Books.

Zawacki, S. J. (1983). Military high technology programs with civilian applications. In *Proceedings of the Fifth National Conference on Communications Technology in Education and Training* (pp. 19-26). ?: Information Dynamics Inc.

Zeigler, B. P. (1976). *Theory of modelling and simulation.* New York, NY: John Wiley & Sons.

Zender, B. F. (1975). *Computers and education in the Soviet Union.* Englewood Cliffs, NJ: Educational Technology Publication.

Zimbardo, P. G. (1982). The state of science. *Psychology today, 16*(May) 59.

Zinn, K. L. (1978). Personal computers at the University of Michigan and an assessment of potential impact. *Creative Computing, 4*(5) 84-87.

APPENDIX A

QUESTIONNAIRE

(Name of instructional device)

1. How many examples of each of the above-named devices did your company produce in total?

   ☐ 1-5 ☐ 6-25 ☐ 26-100 ☐ 101-500 ☐ 501-1000 ☐ 1001-5000 ☐ over 5000

2. How many years were these items in production?

   ☐ 1-5 ☐ 6-10 ☐ 11-15 ☐ 15-20 ☐ over 20 ☐ still in production

3. Which market comprised the largest percentage of sales?

   ☐ general public ☐ educational institutions ☐ corporations ☐ government

4. Which market comprised the **next** largest percentage of sales?

   ☐ general public ☐ educational institutions ☐ corporations ☐ government

5. Which year is closest to the start of production?

   ☐1930 ☐1940 ☐1950 ☐1955 ☐1960 ☐1965 ☐1970 ☐ other _____

6. Which year is closest to the cessation of production?

   ☐1930 ☐1940 ☐1950 ☐1955 ☐1960 ☐1965 ☐1970 ☐ other _____

7. In approximately what price range did the items cost when they were in production?

   ☐$1-$10 ☐$11-25 ☐$26-50 ☐$51-100 ☐$100-200 ☐$201-500 ☐ over $500

8. Does your company possess photographs of the items that I might be able to reproduce in my dissertation?

   ☐ We have no photographs ☐ Yes, but there are charges for use ☐ Yes, but they are unavailable to you

   ☐ No, they are now located at ____.

COMMENTS

APPENDIX B

Teaching machines that appear to follow the principles of Locke

COMPANY	MODEL	DESCRIPTION
SCOTT, FORESMAN & CO. (U.S.A.)	PROOFCHECKER	OVERLAY FOR PENMANSHIP BOOK TO ENABLE TRACING OF LETTERS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
ACETATE PLASTIC	UNK.	Y	N	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Thorndike

COMPANY	MODEL	DESCRIPTION
DEVEREUX FOUNDATION/SMITH-HARRISON INC. (U.S.A.)	50	EPIDIASCOPE; USES PROGRAMMED BOOK; DIAL DRIVEN

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$89.50: 1962

COMPANY	MODEL	DESCRIPTION
GENERAL ATRONICS (U.S.A.)	ATRONIC TUTOR 580	BOOK PROGRAM; 4 CHOICE, PUSH-BUTTON RESPONSE; MACHINE TURNS PAGE WHEN CORRECT RESPONSE SELECTED

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNK.

Teaching machines that appear to follow the principles of Pressey

COMPANY	MODEL	DESCRIPTION
A-ALPHA PATTERN & MANUFACTURING CO. (U.S.A.)	ALPHA MASK	SLIDING MASK AND GUIDE FOR PUNCHING RESPONSES

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL STAMPING	UNK.	N	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
ASTRA (U.S.A.)	AUTOSCORE, MODEL A, MARK II	ELECTRIC PUNCHBOARD, 5 CHOICES; USES SPECIAL QUESTION SHEETS; 10 QUESTIONS MAXIMUM PER SHEET

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	$150.00: 1964

COMPANY	MODEL	DESCRIPTION
CONSOLIDATED LITHO. (U.S.A.)	AUTOSCORE	CHEMICAL ANSWER SHEET; INVISIBLE INK; REQUIRES MOISTENING

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PAPER	UNK.	N	N	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Pressey (continued)

COMPANY	MODEL	DESCRIPTION
DEVEREUX FOUNDATION/SMITH-HARRISON (U.S.A.)	TEACHING AID #80	PUSH-BUTTON RESPONSE; CARD OVERLAYS CONTAIN QUESTIONS; FEEDBACK THROUGH LIGHTS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	$15.00: 1962

COMPANY	MODEL	DESCRIPTION
DEVEREUX FOUNDATION/SMITH-HARRISON (U.S.A.)	TEACHING AID #90	PROGRAM OF 24 SET QUESTIONS; RESPONSE UNIT USING ROTARY SWITCHES; LIGHT & BUZZER FEEDBACK

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DYMEDIA INC. (U.S.A.)	RESPONSE BOARD RB-30	PUSH-BUTTON AUTO SCORER (PUNCHES COMPUTER CARDS); READER IS REQUIRED

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	LIN	$36.00: 1968

COMPANY	MODEL	DESCRIPTION
DYMEDIA INC. (U.S.A.)	DYMEDIA SCORER	READER FOR CARDS PUNCHED BY STUDENT SCORER; SPECIAL CARDS REQUIRED

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	$675.00: 1968

COMPANY	MODEL	DESCRIPTION
ELCO OPTISONICS (U.S.A.)	RESPONDER	ELECTRIC PUNCHBOARD; LAMP GIVES FEEDBACK; CARDS GRADED SEPARATELY

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
GENERAL ATRONICS (U.S.A.)	PORTABLE TAG (TEACHING AND GRADING)	ELABORATE SET OF PUNCHBOARDS WITH QUESTION AND ANSWER ON ONE SHEET

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC CASE	UNK.	N	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
HRB-SINGER (U.S.A.)	STAR 2760	ELECTRIC PUNCHBOARD; COUNTER; FLASHING LIGHT PROVIDES FEEDBACK

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Pressey (continued)

COMPANY	MODEL	DESCRIPTION
INSTRUMENT RESEARCH CO. (U.S.A.)	PUNCHBOARD	PUNCHBOARD

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC CASE	UNK.	N	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
INSTRUMENT RESEARCH CO. (U.S.A.)	MULTIPLE CHOICE	ELECTRIC PUNCHBOARD; HOLDS INDEX CARDS; GREEN LIGHT PROVIDES FEEDBACK

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
LAMSON TECHNICAL PRODUCTS (U.K.)	PROGRAMME BOARD	PUNCHBOARD

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK	N	N	N	LIN	UNK.

COMPANY	MODEL	DESCRIPTION
MODERN TEACHING ASSOCIATES (U.S.A.)	MTA S-R 400	PROGRAM ON FAN-FOLD PAPER; PUSH-BUTTON RESPONSE; M&M REINFORCEMENT DISPENSER

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	$711.00: 1969

COMPANY	MODEL	DESCRIPTION
QUICK RESPONSE SYSTEM INC. (U.S.A.)	RESPONDER BOX	HOLDER FOR IBM CARD; PUNCHBOARD

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	N	N	N	LIN	$8.75: 1968

COMPANY	MODEL	DESCRIPTION
SHAW LABORATORIES, INC. (U.S.A.)	RAPID-RATER	PUNCHBOARD

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	N	N	N	LIN	$4.50: 1965

COMPANY	MODEL	DESCRIPTION
US INDUSTRIES (U.S.A.)	READY REVIEW	FRAME FOR SPECIAL CARD; MULTIPLE-CHOICE RESPONSE; ADVANCE BY STYLUS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL	1963	Y	N	N	LIN	$2.98: 1963

Teaching machines that appear to follow the principles of Pressey (continued)

COMPANY	MODEL	DESCRIPTION
JENSEN, GERALD L. (U.S.A.)	JENSEN'S TUTOR	ENVELOPE-TYPE PUNCHBOARD

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
THIN CARDBOARD	1961	N	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
HONOR PRODUCTS CO. (U.S.A.)	PUSH BUTTON TEACHING MACHINE	BATTERY-POWERED PERFORATED ROLL PROGRAM; 4 PUSH-BUTTON CHOICES

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	1963	Y	Y	N	MLN	$25.00: 1966

Teaching machines combined with audio-visual apparatus,
that appear to follow the principles of Pressey

COMPANY	MODEL	DESCRIPTION
ALDA INSTRUMENTS (CANADA)	MATA SYSTEM	CLASS USE; PUSH-BUTTON RESPONSE STATION; INDICATORS ON TEACHER'S CONSOLE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	$2,500.00: 1968

COMPANY	MODEL	DESCRIPTION
COMPARATOR (U.S.A.)	ARITHMETIC TRAINER	PROGRAM ON SHEET OR IN WORKBOOK; EARPHONE; CLICK INDICATES CORRECT RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
CORRIGAN & ASSOCIATES (U.S.A.)	TELETEST	CLASS USE; PUSH-BUTTON TESTING CONSOLE AND RECORDER; INDICATORS ON TEACHER'S CONSOLE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 30	PROGRAM ON FILM AND TAPE; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	UNKNOWN

Teaching machines combined with audio-visual apparatus, that appear to follow the principles of Pressey (continued)

COMPANY	MODEL	DESCRIPTION
EDEX (U.S.A.)	TEACHING SYSTEM	CLASS USE; PUSH-BUTTON TESTING CONSOLE AND RECORDER; INDICATORS ON TEACHER'S CONSOLE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
EDUCATIONAL PROJECTIONS CORP. (U.S.A.)	STANDARD 888	PROGRAM ON FILMSTRIP; 4 PUSH-BUTTON RESPONSE; GREEN LIGHT & BUZZER FEEDBACK

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	$125.00: 1969

COMPANY	MODEL	DESCRIPTION
INSTRUCTIONAL CONCEPTS (U.S.A.)	TUTOR-SET	AUDIO-VISUAL PROGRAM; PROVISION FOR FEEDBACK

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
INSTUCTIVE DEVICES (U.S.A.)	TESTMATE	PUNCHBOARD WITH AUDIO-VISUAL ATTACHMENTS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	1967	Y	Y	N	LIN	$34.00: 1967

COMPANY	MODEL	DESCRIPTION
KEN COOK COMPANY (U.S.A.)	AUDIOVISION MARK VII	PROGRAM ON SLIDES & LOOPED AUDIO TAPE; 3 CHOICE PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL & PLASTIC	UNK.	Y	Y	N	LIN	$1,500: 1965

COMPANY	MODEL	DESCRIPTION
KEN COOK COMPANY (U.S.A.)	AUDIOVISION MARK 9	PROGRAM ON SLIDES & LOOPED AUDIO TAPE; 3 CHOICE PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
KRS INSTRUMENTS DIVISION, DATAPULSE INC. (U.S.A.)	KRS 6-STACT	PROGRAM ON AUDIO TAPE; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	UNK.	Y	Y	N	LIN	$2:975: 1965

Teaching machines combined with audio-visual apparatus,
that appear to follow the principles of Pressey (continued)

COMPANY	MODEL				DESCRIPTION	
KUNINS ENGINEERING (U.S.A.)	QUIZZO				CLASS USE; PUSH-BUTTON TESTING CONSOLE AND RECORDER; INDICATORS ON TEACHER'S CONSOLE	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL				DESCRIPTION	
LECTRON CORP. (U.S.A.)	MARK I				PROGRAM ON 35 mm SLIDES, MULTI-TRACK AUDIO TAPE; 3-CHOICE PUSH-BUTTON RESPONSE	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL				DESCRIPTION	
LECTRON CORP. (U.S.A.)	MARK V				CLASS USE; REAR PROJECTOR; PUSH-BUTTON RESPONSE PADS; RECORDS RESULTS	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL				DESCRIPTION	
R.V. WEATHERFORD CO. (U.S.A.)	INSTRUCTOSCOPE				TEACHER CONTROL CONSOLE & STUDENT STATIONS WITH PUSH-BUTTON RESPONSE	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	$569.50: 1968

COMPANY	MODEL				DESCRIPTION	
STANDARD (U.S.A.)	VISUAL EDUCATOR 555				PROGRAM ON 35 mm FILMSTRIP; 4 CHOICE, PUSH-BUTTON RESPONSE, RECORDED ON PUNCH TAPE	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
CAST METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL				DESCRIPTION	
TEACHING MACHINES INC./GROLIER (U.S.A.)	MULTIPLE CHOICE				PROGRAM ON 8 mm FILMSTRIP; 4 PUSH-PANEL CHOICES; CORRECT RESPONSE ADVANCES PROGRAM	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL				DESCRIPTION	
TRAINING SYSTEMS (U.S.A.)	RESEARCH				PROGRAM ON 35 mm FILMSTRIP; 4 CHOICE, PUSH-BUTTON RESPONSE	
CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

Teaching machines combined with audio-visual apparatus, that appear to follow the principles of Pressey (continued)

COMPANY	MODEL	DESCRIPTION
VITRO LABORATORIES (U.S.A.)	STUDENT RESPONSE MONITOR SYSTEM	24 UNIT CAPACITY TEACHERS' CONSOLE WITH INDIVIDUAL INDICATORS; 5 CHOICE PUSH-BUTTON STUDENT RESPONSE UNITS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	$750.00: 1969

COMPANY	MODEL	DESCRIPTION
HU-MAC INC. (U.S.A.)	AUTOMATED TEACHING SYSTEM	PROGRAM ON SLIDE & AUDIO TAPE; RESPONSE DETERMINES NEXT DISPLAY AND MESSAGE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	MLN	$1,500.00: 1968

COMPANY	MODEL	DESCRIPTION
KEN COOK COMPANY (U.S.A.)	**SR 100 STUDENT CONSOLE**	PROGRAM ON 16 mm FILMSTRIP LOOP WITH 4-TRACK AUDIO TAPE; 4 CHOICE, PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	1975	Y	Y	Y	MLN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
MOTIVA, LTD. (U.S.A.)	ED	PROGRAM ON SLIDES AND AUDIO TAPE; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	MLN	$800.00: 1969

COMPANY	MODEL	DESCRIPTION
PACKARD BELL (U.S.A.)	AVR-1 (AUDIO-VISUAL-RESPONSE SYSTEM)	PROGRAM ON SLIDE AND AUDIO TAPE; PUSH-BUTTON RESPONSE; SOLID-STATE UNIT

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC AND METAL	1962	Y	Y	N	MLN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
ILLIAMS RESEARCH U.S.A.)	***SCIENCE DESK***	PROGRAM ON16 mm FILM WITH SOUND; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	NEVER	Y	Y	N	UNK	N/A

Teaching machines that appear to follow the principles of Briggs

COMPANY	MODEL	DESCRIPTION
EDUCATIONAL SUPPLY ASSOCIATION (U.K.)	CANTERBURY MARK II	PROGRAM ON PUNCHED CARDS; CARD DROPS IF CORRECT RESPONSE SELECTED

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	LIN	£21: 1968

COMPANY	MODEL	DESCRIPTION
TEACHALL CORPORATION/U.S. PHOTO SUPPLY/PUBLISHERS COMPANY INC. (U.S.A.)	TEACHALL DRILLMASTER	PROGRAM ON NOTCHED CARDS; FIVE CHOICE, PUSH-BUTTON RESPONSE; BATTERY OPERATED

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL & PLASTIC	UNK.	Y	Y	N	LIN	$49.50: 1968

Teaching machines that appear to follow the principles of Buitenkand

COMPANY	MODEL	DESCRIPTION
RENNER, INC./VAN VALKENBURGH, NOOGER & NEVILLE (U.S.A.)	TRAINER-TESTER	PROGRAM SHEET WITH ERASEABLE SILVER INK OVERLAY

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
CARDBOARD & PLASTIC	UNK.	N	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
TEACHING MACHINES INC./GROLIER (U.S.A.)	19.84	SHEET PROGRAM; OVERLAY OF ADHESIVE STRIPS; DESIGNED FOR RE-USE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	N	N	LIN	$20.00: 1962

COMPANY	MODEL	DESCRIPTION
VAN VALKENBURGH, NOOGER & NEVILLE, INC. (U.S.A.)	TRAINER-TESTER	SIMULATOR KIT; RESPONSE SHEETS WITH ERASEABLE OVERLAYS OBSCURING SUPPLEMENTAL INFORMATION

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
CARDBOARD & PAPER	UNK.	N	N	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Nelson

COMPANY	MODEL	DESCRIPTION
MANAGEMENT RESEARCH ASSOCIATES (U.S.A.)	SELF TRAINER	PEEL BACK OVERLAYS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PAPER	1954	N	N	N	LIN	15¢: 1965

Teaching machines that appear to follow the principles of Skinner

COMPANY	MODEL	DESCRIPTION
A-ALPHA PATTERN & MANUFACTURING CO. (U.S.A.)	ALPHA	PAPER ROLL PROGRAM; SEPARATE PUNCH ANSWER TAPE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL CASE	UNK.	Y	N	N	LIN	UNK.

COMPANY	MODEL	DESCRIPTION
A.H.B. PRODUCTS (U.S.A.)	SEMI-AUTOMATIC	PAPER ROLL PROGRAM

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
AVTA CORP. (U.S.A.)	110	PAPER ROLL PROGRAM; SEPARATE ROLL FOR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
BERKELEY ENTERPRISES, INC. (U.S.A.)	K 33	TEACHING MACHINE KIT; 70 VERSIONS POSSIBLE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	$19.95: 1964

COMPANY	MODEL	DESCRIPTION
BILLERET CO./TEACHING MACHINES INC. (U.S.A.)	TM-3 DISCOVERER	PAPER ROLL PROGRAM;SEPARATE ROLL FOR RESPONSE; STAR PUNCH FOR REGISTERING RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	N	N	LIN	$38.75: 1964

COMPANY	MODEL	DESCRIPTION
CENTRAL SCIENTIFIC CO. (U.S.A.)	PROGRAMMED LEARNER SERIES	PAPER SHEET PROGRAM; PAPER ROLL FOR RESPONSE; 2 CHOICE RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC CASE	1963	Y	N	N	LIN	$2.95: 1965

COMPANY	MODEL	DESCRIPTION
CONSOLIDATED LITHO. (U.S.A.)	EDUMATOR	PAPER ROLL PROGRAM; SEPARATE ROLL FOR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
CARDBOARD CASE	UNK.	Y	N	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Skinner (continued)

COMPANY	**MODEL**				**DESCRIPTION**	
DEVEREUX FOUNDATION/SMITH-HARRISON (U.S.A.)	TEACHING AID #50				WORKBOOK KEYED TO PUSH-BUTTONS ON MACHINE; RESPONSE YIELDS FEEDBACK LIGHTS	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC & SHEET METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	**MODEL**				**DESCRIPTION**	
DYNA SLIDE CO. (U.S.A.)	VERTIMASK SLIDE-A-MASK				SLIDER MASK	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC	UNK.	N	N	N	LIN	$40.00: 1962

COMPANY	**MODEL**				**DESCRIPTION**	
ED-U-CARDS MFG. CORP. (U.S.A.)	ED-U-DATA				SHEET PROGRAM; OBSCURED ANSWER; LIGHT IN CASE INDICATES CORRECT RESPONSE	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC & METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	**MODEL**				**DESCRIPTION**	
EDUCATIONAL SUPPLY ASSOCIATION (U.K.)	ESATUTOR				PROGRAM ON CARDS; CONSTRUCTED RESPONSE; COMPARISON	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
UNKNOWN	UNK.	Y	Y	N	LIN	£14: 1963

COMPANY	**MODEL**				**DESCRIPTION**	
ENCYCLOPAEDIA BRITANNICA FILMS (U.S.A.)	TEMAC				SLIDER MASK	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC	UNK.	N	N	N	LIN	UNKNOWN

COMPANY	**MODEL**				**DESCRIPTION**	
FARRALL INSTRUMENT CO. (U.S.A.)	***TOUCH-TUTOR MARK 2M***				VISUAL PRESENTATION; TOUCH RESPONSE; AUDITORY AND OPTICAL FEEDBACK; CANDY REINFORCEMENT	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
UNKNOWN	NEVER	Y	Y	N	LIN	N/A

COMPANY	**MODEL**				**DESCRIPTION**	
FIELD ENTERPRISES/WORLD BOOK (U.S.A.)	CYCLO TEACHER				PROGRAM ON 14 INCH (356 mm) ø PAPER DISK; CONSTRUCTED RESPONSE ON SEPARATE SHEET	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC	1960	Y	N	N	LIN	$15.00: 1965

Teaching machines that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
FORINGER INC. (U.S.A.)	OSLER-FORINGER DISCRIMINATION DEVICE #1231	PROGRAM ON 35 mm FILMSTRIP; LEVER SYSTEM, MARBLE REINFORCEMENT, AUTO SCORING

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$80.00: 1962

COMPANY	MODEL	DESCRIPTION
FORINGER INC. (U.S.A.)	#2002	PAPER SHEET PROGRAM; CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
FORINGER INC. (U.S.A.)	MINIATURE DISPLAY-CELL DEVICE #1224	LAMP BOARD; SYMBOLS AND SWITCHES

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
GRAFLEX (U.S.A.)	MICRO-AID	PROGRAM ON 35 mm FILMSTRIP; WORKBOOK FOR CONSTRUCTING RESPONSE; LEVER PULL REVEALS CORRECT RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
H.C.P. PRODUCTS LTD. (U.K.)	TASKMASTER	CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK	Y	N	N	LIN	£2/19s: 1963

COMPANY	MODEL	DESCRIPTION
HAMILTON (U.S.A.)	VISITUTOR #200	PROGRAM ON CARDS; RESPONSES CONSTRUCTED ON SEPARATE SHEET; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
INSTITUTET FOR PROGRAMMERAD UNDERVISNING (SWEDEN)	PIL	PROGRAM ON PAPER SHEETS; CONSTRUCTED RESPONSE MADE ON PROGRAM SHEETS; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	Y	N	N	LIN	98 KR. 1965

Teaching machines that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
INTERNATIONAL TEACHING MACHINES (U.K.)	GRUNDYMASTER	PROGRAM SHEETS; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	1963	Y	N	N	LIN	£20: 1968

COMPANY	MODEL	DESCRIPTION
J. HAIGH (U.K.)	HAIGHTUTOR	CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK	Y	N	N	LIN	UNK.

COMPANY	MODEL	DESCRIPTION
KEE INCORPORATED (U.S.A.)	KEE-SKIL-TYPE	CONNECTED TO TYPEWRITER; ERROR PRODUCES SIGNAL

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL	UNK.	Y	Y	N	LIN	$1,188.00: 1969

COMPANY	MODEL	DESCRIPTION
KONCEPT-O-GRAPH CORP./GRAFLEX (U.S.A.)	KOG-7	PROGRAM ON PAPER ROLL; SPECIAL ANSWER ROLL UNIT MAY BE USED BOTH BY LEFT AND RIGHT-HANDED INDIVIDUALS; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & SHEET METAL	UNK.	Y	N	N	LIN	$75.00:1964

COMPANY	MODEL	DESCRIPTION
LAMSON TECHNICAL PRODUCTS (U.K.)	HILLBOROUGH	CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK	Y	N	N	LIN	UNK.

COMPANY	MODEL	DESCRIPTION
MACMILLAN EDUCATIONAL CO. (U.S.A.)	**E.L.F. (EARLY LEARNING FUN)**	ICONIC RECOGNITION; MAGNETIC DOTS ACTUATE SOUND IN FEEDBACK WAND

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	Y	Y	Y	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
MULTIMATIC (U.S.A.)	TUTOR-MATIC	DISK PROGRAM; KEYPAD INPUT (ALPHA-NUMERIC); COMPETITION ABILITY

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
NATIONAL BLANK BOOK CO. (U.S.A.)	LEARN EASE	SEVERAL TYPES OF SLIDER MASKS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	N	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
NATIONAL EDUC. SYSTEMS (U.S.A.)	PROTOTYPE	PROGRAM ON PAPER ROLL; CONSTRUCTED RESPONSE ON SEPARATE PAD

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
PACKMAN RESEARCH LTD. (U.K.)	TUTORPACK MODEL B	PROGRAM ON PAPER SHEET; CONSTRUCTED RESPONSE ON SEPARATE SHEET; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	LIN	£8: 1967

COMPANY	MODEL	DESCRIPTION
PROGRAMED TEACHING AIDS (U.S.A.)	FERSTER TUTOR #2010	PROGRAM ON PAPER SHEET; CONSTRUCTED RESPONSE ON SEPARATE SHEET; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
CARDBOARD CASE	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
PROGRAMED TEACHING AIDS (U.S.A.)	FORINGER 2002	PROGRAM ON FAN-FOLD PAPER; CONSTRUCTED RESPONSE ON SEPARATE ROLL; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
RHEEM-CALIFONE (U.S.A.)	*DIDAK 101*	PROGRAM ON FAN-FOLD PAPER; PUSH-PANEL RESPONSE; ADVANCES ON CORRECT SELECTION

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL & PLASTIC	NEVER	Y	Y	N	LIN	N/A

COMPANY	MODEL	DESCRIPTION
RHEEM-CALIFONE (U.S.A.)	DIDAK 501	PROGRAM ON FAN-FOLD PAPER; SEPARATE ANSWER TAPE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	N	N	LIN	$157.50: 1964

Teaching machines that appear to follow the principles of Skinner (continued)

COMPANY	**MODEL**				**DESCRIPTION**	
RHEEM-CALIFONE (U.S.A.)	***DIDAK 601***				PROGRAM ON FAN-FOLD PAPER; PUSH-PANEL RESPONSE; ADVANCES ON CORRECT SELECTION; AUTO SCORE	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
SHEET METAL & PLASTIC	NEVER	Y	Y	N	LIN	N/A

COMPANY	**MODEL**				**DESCRIPTION**	
STATEN, J. F. (U.S.A.)	NONE				PROGRAM ON PAPER ROLL; CONSTRUCTED RESPONSE; COMPARISON	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC	UNK.	Y	N	N	LIN	UNKNOWN

COMPANY	**MODEL**				**DESCRIPTION**	
TEACHING MACHINES INC./GROLIER (U.S.A.)	MIN/MAX HOME				PROGRAM ON PAPER SHEETS; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; COMPARISON	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
SHEET METAL & PLASTIC	UNK.	Y	N	N	LIN	$20.00: 1962

COMPANY	**MODEL**				**DESCRIPTION**	
TEACHING MACHINES INC./GROLIER (U.S.A.)	MIN/MAX MODEL II				PROGRAM ON PAPER SHEETS; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; COMPARISON	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
SHEET METAL & PLASTIC	UNK.	Y	N	N	LIN	$25.00: 1962

COMPANY	**MODEL**				**DESCRIPTION**	
TEACHING MACHINES INC./GROLIER (U.S.A.)	**MIN/MAX MODEL III**				PROGRAM ON PAPER SHEETS; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; COMPARISON	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
PLASTIC	UNK.	Y	N	Y	LIN	$25.00: 1965

COMPANY	**MODEL**				**DESCRIPTION**	
UNIVERSAL ELECTRONICS (U.S.A.)	UNIVOX				PROGRAM ON PAPER SHEETS; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; COMPARISON	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
METAL & PLASTIC	UNK.	Y	N	N	LIN	UNKNOWN

Teaching machines that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
USI ROBIDYNE (U.S.A.)	MEMOTUTOR	PROGRAM AND RESPONSE CHOICES ON DRUMS; STUDENT MATCHES; ERROR COUNT

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

Teaching machines combined with audio-visual apparatus,
that appear to follow the principles of Skinner

COMPANY	MODEL	DESCRIPTION
ACS (U.S.A.)	PORTABLE AV UNIT	PROGRAM ON 35 mm FILMSTRIP & REEL TO REEL TAPE, SYNCHRONIZED; SEPARATE ANSWER ROLL

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
ALDA INSTRUMENTS (CANADA)	MSK	SPECIAL PIANO KEYBOARD WITH INDICATION ON TEACHER CONSOLE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
AMERICAN TEACHING SYSTEMS (U.S.A.)	834	PROGRAM ON 35 mm FILMSTRIP & 4-TRACK TAPE; COUPLED ANSWER SCROLL & PROVISION FOR VERBAL INPUT

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
APPLIED COMMUNICATIONS SYSTEMS (U.S.A.)		PROGRAM ON 35mm SLIDES; CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
AVID CORPORATION (U.S.A.)	AVIDESK	PROGRAM ON FILMSTRIP; SEPARATE ANSWER STRIP

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	$300.00: 1970

Teaching machines combined with audio-visual apparatus, that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
AVTA CORP. (U.S.A.)	440	PROGRAM ON 35 mm FILMSTRIP & 4-TRACK TAPE; COUPLED ANSWER ROLL; PROVISION FOR VERBAL INPUT

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
BEHAVIOURAL RESEARCH AND DEVELOPMENT LTD. (U.K.)	TEDDINGTON TOUCH TUTOR MARK II	PUSH-PANEL RESPONSE; AUDITORY CONFIRMATION

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	LIN	£500: 1968

COMPANY	MODEL	DESCRIPTION
CONCORD CONTROL (U.S.A.)	FRONT PROJECTION	PROGRAM ON 35 mm STRIP; COUPLED ROLL FOR CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DUKANE CORPORATION (U.S.A.)	REDI-TUTOR #5765	PROGRAM ON 35 mm STRIP; COUPLED ROLL FOR CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$165.00: 1967

COMPANY	MODEL	DESCRIPTION
DUKANE CORPORATION (U.S.A.)	TUTOR RITE #99A230	CONSTRUCTED RESPONSE ACCESSORY FOR REDI TUTOR

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$92.30: 1967

COMPANY	MODEL	DESCRIPTION
EASTMAN KODAK (U.S.A.)	MENTOR I	PROGRAM ON 16 mm FILMSTRIP; RESPONSE UNIT REVEALS CORRECT RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL &PLASTIC	1960	Y	Y	N	MLN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
EASTMAN KODAK (U.S.A.)	MENTOR II	PROGRAM ON16 mm FILMSTRIP; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; LEVER TYPE OPERATION

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL &PLASTIC	1962	Y	Y	N	MLN	UNKNOWN

Teaching machines combined with audio-visual apparatus,
that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
HAMILTON (U.S.A.)	FILMCARD VISITUTOR	PROGRAM ON 35 mm FILMSTRIP; SEPARATE SHEET FOR CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
HAMILTON (U.S.A.)	AUDITUTOR	PROGRAM ON AUDIO TAPE; VERBAL INPUT; AUDIO RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
HAMILTON (U.S.A.)	COMBINATION AUDIO-VISUAL	COMBINED FILMCARD VISITUTOR AND AUDITUTOR

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
HUGHES AIRCRAFT CO., NOW WEATHERFORD COMPANY (U.S.A.)	VIDEOSONIC PROGRAMMER 102BR	AUDIO-VISUAL PROGRAM; PROVISION FOR SELF-RECORDING

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$749.50: 1966

COMPANY	MODEL	DESCRIPTION
LANGUA-LAB, INC. (U.S.A.)	LANGUA-LEARNER	PROGRAM ON AUDIO TAPE AND/OR FILMSTRIP; CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	1700	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE ON AUTO-ADVANCED PAPER ROLL

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	1962	Y	Y	N	LIN	$245.00: 1965

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	1700-B	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE ON SEPARATE SHEET; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	1962	Y	Y	N	LIN	$245.00: 1965

Teaching machines combined with audio-visual apparatus,
that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	1700-BT	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE ON SEPARATE SHEET; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	1962	Y	Y	N	LIN	$245.00: 1965

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	1700-S	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE ON AUTO-ADVANCED PAPER ROLL

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	1962	Y	Y	N	LIN	$310.00: 1965

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	1700-SB	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE ON SEPARATE SHEET; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	1962	Y	Y	N	LIN	$275.00: 1965

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	1700-T	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE ON AUTO-ADVANCED PAPER ROLL

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	1962	Y	Y	N	LIN	$495.00: 1965

COMPANY	MODEL	DESCRIPTION
MCMAHON ELECTRONIC ENGINEERING	SPEED MODEL 2100	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE OR RESPONSE WITH PUSH-BUTTONS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL	UNK.	Y	Y	N	LIN	$495.00: 1969

COMPANY	MODEL	DESCRIPTION
MCMAHON ELECTRONIC ENGINEERING (U.S.A.)	SPEED MODEL 200	PROGRAM ON 35mm SLIDES; CONSTRUCTED RESPONSE OR RESPONSE WITH PUSH-BUTTONS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL	UNK.	Y	Y	N	LIN	$1,250.00: 1969

COMPANY	MODEL	DESCRIPTION
RECORDAK, SUBSIDIARY OF EASTMAN KODAK (U.S.A.)	MENTOR	PROGRAM ON16 mm FILMSTRIP; SEPARATE PAD FOR CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

Teaching machines combined with audio-visual apparatus,
that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
UNIVERSITY OF SHEFFIELD (U.K.)	PROTOTYPE	PROGRAM ON 35mm FILMSTRIP; CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL	1963	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
VIDEOSONIC SYSTEMS, DIVISION OF HUGHES AIRCRAFT CO. (U.S.A.)	CLASSMATE-1; 102B500	CLASS USE; PROGRAM ON35 mm SLIDES, 4-TRACK AUDIO TAPE; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; VERBAL RECORDING; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$749.50: 1965

COMPANY	MODEL	DESCRIPTION
VIDEOSONIC SYSTEMS, DIVISION OF HUGHES AIRCRAFT CO. (U.S.A.)	PRESENTOR; 102B	PROGRAM ON35 mm SLIDES, 4-TRACK AUDIO TAPE; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; VERBAL RECORDING; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$559.50: 1965

COMPANY	MODEL	DESCRIPTION
VIDEOSONIC SYSTEMS, DIVISION OF HUGHES AIRCRAFT CO. (U.S.A.)	PROGRAMMER; 102BR	PROGRAM ON35 mm SLIDES, 4-TRACK AUDIO TAPE; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; VERBAL RECORDING; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	$699.50: 1965

COMPANY	MODEL	DESCRIPTION
VIEWLEX (U.S.A.)	VIEWTEACH 77	PROGRAM ON 35 mm FILMSTRIP, 8 mm MOVIE FILM; SEPARATE ROLL FOR CONSTRUCTED RESPONSE; COMPARISON

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	LIN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 99S	MODIFICATION OF SINGER TELEX AUTO-VANCE IV; AUDIO-VISUAL PROGRAM; 4-CHOICE, PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	1975	Y	Y	Y	MLN	$197.50: 1988

Teaching machines combined with audio-visual apparatus, that appear to follow the principles of Skinner (continued)

COMPANY	MODEL	DESCRIPTION
LAMSON TECHNICAL PRODUCTS (U.K.)	EMPIRICAL TUTOR MARK II	UNKNOWN

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	MLN	UNK.

Teaching machines that appear to follow the principles of both Pressey and Skinner

COMPANY	MODEL	DESCRIPTION
BRISTOL TUTOR GROUP (U.K.)	TUTOR TEACHING MACHINE	PROGRAM ON 320 FRAME SPOOL; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	COM	£125: 1967

COMPANY	MODEL	DESCRIPTION
CLEMENTS BROTHERS LTD. (U.K.)	CLEMENTS	DESK-TYPE CONSOLE; PROGRAM MAY USE FILMSTRIP AND AUDIO TAPE; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL & WOOD	UNK	Y	Y	N	COM	£130: 1963

COMPANY	MODEL	DESCRIPTION
CORRIGAN & ASSOCIATES (U.S.A.)	TELEPACER	PROGRAM ON SLIDES OR FILMSTRIP; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	COM	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 10	PROGRAM ON FILM STRIP; 3 CHOICE, PUSH-BUT[illegible]PONSE; FEEDBACK THROU[illegible]UCTIVE INK CODING

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COS[illegible]AR
PLASTIC & METAL	UNK.	Y	Y	N	COM	$50.00: 1967

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 20 AVTM	PROGRAM ON 7 INCH (178 mm) 16 R.P.M. PHONOGRAPH DISKS & PAPER ROLL; PUSH-BUTTON, CONSTRUCTED & VOICE RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	UNK.	Y	Y	N	COM	$50.00: 1965

Teaching machines that appear to follow the principles of both Pressey and Skinner (continued)

COMPANY	MODEL	DESCRIPTION
EDUCATIONAL SYSTEMS LTD. (U.K.)	TM 1024	PROGRAM ON1024 FRAME CAPACITY 35 mm FILM; YES/NO PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	COM	£295: 1967

COMPANY	MODEL	DESCRIPTION
EDUCATIONAL SYSTEMS LTD. (U.K.)	RA 1024	SIMILAR TO TM 1024, BUT WITH DIAL INDICATOR FOR RANDOM ACCESS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	COM	£585: 1967

COMPANY	MODEL	DESCRIPTION
HUGHES AIRCRAFT CO., NOW WEATHERFORD COMPANY (U.S.A.)	VIDEOSONIC CLASSMATE 500	AUDIO-VISUAL PROGRAM; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	COM	$799.50: 1966

COMPANY	MODEL	DESCRIPTION
HUGHES AIRCRAFT CO., NOW WEATHERFORD COMPANY (U.S.A.)	VIDEOSONIC EDUTRAINER 901	AUDIO-VISUAL PROGRAM; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	COM	$399.50: 1966

COMPANY	MODEL	DESCRIPTION
HUGHES AIRCRAFT CO., NOW WEATHERFORD COMPANY (U.S.A.)	VIDEOSONIC RESEARCH MODEL	AUDIO-VISUAL PROGRAM; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	COM	UNKNOWN

COMPANY	MODEL	DESCRIPTION
HUGHES AIRCRAFT CO., NOW WEATHERFORD COMPANY (U.S.A.)	VIDEOSONIC STUDENT	AUDIO-VISUAL PROGRAM; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	COM	UNKNOWN

COMPANY	MODEL	DESCRIPTION
MODERN TEACHING ASSOCIATES, INC., LATER BEHAVIORAL CONTROLS (U.S.A.)	MTA 100 SCHOLAR	PROGRAM ON FAN-FOLD PAPER; PUSH-BUTTON OR CONSTRUCTED RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL AND PLASTIC	UNK.	Y	Y	N	COM	$329.00: 1965

Teaching machines that appear to follow the principles of both Pressey and Skinner (continued)

COMPANY	MODEL	DESCRIPTION
TEACHING MACHINES INC./GROLIER (U.S.A.)	WYKOFF FILM TUTOR	PROGRAM ON 35 mm FILMSTRIP; KEYBOARD CONSTRUCTED & MULTIPLE-CHOICE RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
FIBREBOARD & METAL	UNK.	Y	Y	N	COM	UNKNOWN

COMPANY	MODEL	DESCRIPTION
VISUAL PROGRAMMING INC. (U.S.A.)	VPI 700B	PROGRAM ON 35 mm FILMSTRIP IN CARTRIDGE; PUSH-BUTTON AND CONSTRUCTED RESPONSES

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	Y	Y	N	COM	$120.00: 1967

COMPANY	MODEL	DESCRIPTION
COLUMBIA BROADCASTING SYSTEM (U.S.A.)	VIEWLEX AVS-10	DISK PROGRAM; PUSH-BUTTON RESPONSE; VISUAL FEEDBACK

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	MLN	$345.00: 1968

Teaching machines that appear to follow the principles of Crowder

COMPANY	MODEL	DESCRIPTION
BORG-WARNER/NOW MANUFACTURED BY EDUCATIONAL TECHNOLOGY, A DIVISION OF JOSTENS (U.S.A.)	**SYSTEM 80**	PROGRAM ON PUNCHED CARD WITH MICROFICHE SLIDES, PHONOGRAPH RECORDS; 5 CHOICE, PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	1968	Y	Y	Y	BRN	$635.00: 1968

COMPANY	MODEL	DESCRIPTION
DIDACTICS CORPORATION (U.S.A.)	**DIDACTOR DTR 300**	PORTABLE UNIT, WEIGHS 15 LBS. (6.8 Kg)

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	1965	Y	Y	Y	BRN	$485.00: 1967

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 50	PROGRAM ON FILM AND AUDIO TAPE; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	BRN	UNKNOWN

Teaching machines that appear to follow the principles of Crowder (continued)

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 70	VARIANT OF MODEL 50; PROGRAM ON SUPER 8 mm FILM PROJECTED ON 5 INCH (127 mm) SCREEN

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	BRN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 85	VARIANT OF MODEL 70; PROGRAM ON 1/4 INCH AUDIO TAPE AND 120 FORMAT SLIDES; 8 INCH (203 mm) SCREEN

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	UNK.	Y	Y	N	BRN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
DORSETT INDUSTRIES INC. (U.S.A.)	M 86	VARIANT OF MODEL 85; PROGRAM ON 35 mm FILMSTRIPS; PHONOGRAPH DISKS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC & METAL	1962	Y	Y	N	BRN	$200.00: 1969

COMPANY	MODEL	DESCRIPTION
EDUCATION ENGINEERING (U.S.A.)	SPEED	PROGRAM ON 35 mm SLIDES; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	UNK.	Y	Y	N	BRN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
EDUCATIONAL SYSTEMS LTD. (U.K.)	TM 198	PROGRAM ON MICROFICHE; 8 CHOICE, PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	BRN	£130: 1967

COMPANY	MODEL	DESCRIPTION
INFORMATION TRANSFER CORP. (U.S.A.)	SLATE	TOUCHCARDS WITH SOUND STRIPS & ELECTONIC PROGRAM CONTROL

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	BRN	$900.00: 1970

COMPANY	MODEL	DESCRIPTION
INTERNATIONAL TEACHING MACHINES (U.K.)	GROUP TUTOR	CLASS USE; SIMILAR TO GRUNDYTUTOR, BUT DESIGNED FOR GROUP USE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	BRN	£445: 1968

Teaching machines that appear to follow the principles of Crowder (continued)

COMPANY	MODEL	DESCRIPTION
INTERNATIONAL TEACHING MACHINES (U.K.)	GRUNDYTUTOR	PROGRAM ON 35 mm FILM; 11 CHOICE, PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
METAL & PLASTIC	1962	Y	N	N	BRN	£230: 1963

COMPANY	MODEL	DESCRIPTION
MAST DEVELOPMENT COMPANY/KEYSTONE VIEW COMPANY (U.S.A.)	143	PROGRAM ON 35 mm FILMSTRIP & AUDIO TAPE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	1962	Y	Y	N	BRN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
NORTH AMERICAN PHILIPS COMPANY, INC. (U.S.A.)	EL 9000	PROGRAM ON 198 MICROFICHE FRAMES; 8 CHOICE, PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	Y	N	BRN	UNKNOWN

COMPANY	MODEL	DESCRIPTION
PSYCHOTECHNICS, INC. (U.S.A.)	RX READING PROGRAM	PROGRAM ON AUDIO TAPE; NUMBERBOARD RESPONSE; FEEDBACK INDICATES AREAS OF WEAKNESS

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
UNKNOWN	UNK.	Y	N	N	BRN	$562.25: 1970

COMPANY	MODEL	DESCRIPTION
USI WESTERN DESIGN/U S INDUSTRIES (U.S.A.)	AUTOTUTOR MARK I	PROGRAM ON 35 mm FILM; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
SHEET METAL & PLASTIC	1959	Y	Y	N	BRN	$5,000-$7,000: 1961

COMPANY	MODEL	DESCRIPTION
USI WESTERN DESIGN/U S INDUSTRIES (U.S.A.)	AUTOTUTOR MARK II	PROGRAM ON 35 mm FILM; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	1961	Y	Y	N	BRN	$1,200.00: 1961

COMPANY	MODEL	DESCRIPTION
WELCH SCIENTIFIC (U.S.A.)	AUTOTUTOR MARK III	PROGRAM ON 35 mm FILM; PUSH-BUTTON RESPONSE

CONSTRUCTION	YRIN	MEC	ELE	IP	PRGTP	COST:YEAR
PLASTIC	UNK.	Y	Y	N	BRN	$1,250.00: 1968

Special type of teaching machine

COMPANY	MODEL				DESCRIPTION	
E-Z SORT SYSTEMS/ROYAL MCBEE (U.S.A.)	INSTRUCTOCARD				CARDS WITH PUNCHED HOLES ALONG PERIMETER; STICK USED TO SELECT PARTICULAR CARDS	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
CARDBOARD	UNK.	N	N	N	BRN	UNK.

Teaching machines uncategorized because of insufficient information

COMPANY	MODEL				DESCRIPTION	
LEARNING MACHINES INC. (U.S.A.)	7 MODELS (NO DETAILS)				UNKNOWN	
CONSTRUCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
UNKNOWN	UNK.			N	UNK	UNK.

COMPANY	MODEL				DESCRIPTION	
RAYTHEON RESPONSE LEARNING SYSTEMS (U.S[illegible]	RESPONSE LEARNING SYSTEMS				VARIOUS SYSTEMS; NO DETAILS	
[illegible]UCTION	**YRIN**	**MEC**	**ELE**	**IP**	**PRGTP**	**COST:YEAR**
UN[illegible]	UNK.	Y	Y	N	UNK	UNK.

APPENDIX C

FULL NAME	ACRONYM	LANGUAGE TYPE
ALGOrithmic Language	ALGOL	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Several computer types	

FULL NAME	ACRONYM	LANGUAGE TYPE
Applied Logic COMputing	ALCOM	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Unknown	

FULL NAME	ACRONYM	LANGUAGE TYPE
A Programming Language	APL	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Several computer types	An interpreted language especially suited to matrix operations. Has also been used for instructional purposes

FULL NAME	ACRONYM	LANGUAGE TYPE
Austin Rover Programming LANguage	ARPLAN	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Unknown	Based on PILOT, but written in C language; designed for a specific industrial concern

FULL NAME	ACRONYM	LANGUAGE TYPE
BASEBALL	BASEBALL	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Unknown mainframe computer	A questioning-answering presentation using a database of baseball information

FULL NAME	ACRONYM	LANGUAGE TYPE
Beginners All purpose Symbolic Instruction Code	BASIC	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Several computer types	Used extensively for instructional purposes, but was not designed for such applications

FULL NAME	ACRONYM	LANGUAGE TYPE
BOOK	BOOK	PROGRAMMING

COMPUTER OR SYSTEM	COMMENTS
Several computer types	Developed in Japan, based on COMCAL; adds authoring commands to programming languages such as FORTRAN

FULL NAME BRown University INteractive language	ACRONYM BRUIN	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Unknown	COMMENTS	

FULL NAME Computer Aided Instruction SYStem-8	ACRONYM CAISYS-8	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM PDP 8/E minicomputer	COMMENTS Consists of a compiler that accepts input from paper tape, containing the program written by the teacher; a loader and an operating system	

FULL NAME COMmand driven Computer Assisted Learning	ACRONYM COMCAL	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Severalcomputer types	COMMENTS Adds authoring commands to programming languages such as FORTRAN	

FULL NAME COMmon Algorithmic Language	ACRONYM COMAL	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Several computer types	COMMENTS	

FULL NAME COmmon Business Oriented Language	ACRONYM COBOL	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Several computer types	COMMENTS	

FULL NAME Compiler for Automatic Teaching Operation	ACRONYM CATO	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM PLATO II	COMMENTS Based on Fortran-60	

FULL NAME Conversational Algebraic Language	ACRONYM CAL	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Several computer types	COMMENTS	

FULL NAME	ACRONYM	LANGUAGE TYPE
DIalect of ALGOL	DIALGOL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Designed to simplify programming	

FULL NAME	ACRONYM	LANGUAGE TYPE
Direct English Access and CONtrol	DEACON	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Unknown mainframe computer	Probably unavailable commercially	

FULL NAME	ACRONYM	LANGUAGE TYPE
DYnamic STorage ALlocation	DYSTAL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
IBM 7070 mainframe computer		

FULL NAME	ACRONYM	LANGUAGE TYPE
Educational Language Facility	E.L.F.	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Some VAX minicomputers	Designed for developing other languages to use in instructional settings	

FULL NAME	ACRONYM	LANGUAGE TYPE
File Oriented Interpretive Language	FOIL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types		

FULL NAME	ACRONYM	LANGUAGE TYPE
FOrmula CALculator	FOCAL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Some Digital Equipment mainframe computes	No connection with FOCAL authoring language	

FULL NAME	ACRONYM	LANGUAGE TYPE
FORmula TRANslating system	FORTRAN	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Has been used for instructional purposes because of general availability, but is not suited ideally for them	

FULL NAME General Purpose Systems Simulator	ACRONYM GPSS	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Several mainframe computers	COMMENTS For designing simulations	

FULL NAME GRAphic Input Language	ACRONYM GRAIL	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Several computer types	COMMENTS Designed for graphics programming	

FULL NAME INFORM	ACRONYM INFORM	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Philco-Ford 211 computer	COMMENTS	

FULL NAME Instructional System Language, 1st version	ACRONYM ISL-1	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM RCA Spectra 70/45 mainframe computers	COMMENTS Similar in nature to IBM's Coursewriter II	

FULL NAME Irvine Symbolic Interpretive System	ACRONYM ISIS	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM IBM 360 mainframe computer	COMMENTS	

FULL NAME Johnniac Open Shop System	ACRONYM JOSS	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Rand Johnniac mainframe computer	COMMENTS	

FULL NAME Jules Own Version of the International Algebraic Language	ACRONYM JOVIAL	LANGUAGE TYPE PROGRAMMING
COMPUTER OR SYSTEM Philco S2000 computer	COMMENTS	

FULL NAME	ACRONYM	LANGUAGE TYPE
Language for the On-Line Investigation and Transformation of Abstractions	LOLITA	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several mainframe computers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Language of Arithmetic Required of Kindergarten	LARK	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Unknown		

FULL NAME	ACRONYM	LANGUAGE TYPE
LISt Processor	LISP	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Also INTERLISP, a special dialect developed for artificial intelligence (AI)	

FULL NAME	ACRONYM	LANGUAGE TYPE
LOGO (also known as Baby LISP)	LOGO	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Can drive a mechanical device called a turtle; language used commonly in elementary schools	

FULL NAME	ACRONYM	LANGUAGE TYPE
NELIAC	NELIAC	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	A dialect of ALGOL	

FULL NAME	ACRONYM	LANGUAGE TYPE
Pascal	PASCAL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Named after Blaisé Pascal	

FULL NAME	ACRONYM	LANGUAGE TYPE
PICTO	PICTO	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
PLATO IV	Designed for use by young children who have not yet learned to read. Instructions about picture commands are provided by computer audio	

FULL NAME	ACRONYM	LANGUAGE TYPE
Pittsburgh Interpretive Language	PIL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Mainframe computers operating with Michigan Terminal System (MTS)		

FULL NAME	ACRONYM	LANGUAGE TYPE
Programming Language, 1st version	PL/1	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Claimed by some to be the best of COBOL and FORTRAN; there are later versions of this language as well	

FULL NAME	ACRONYM	LANGUAGE TYPE
PROgramming LOGic	PROLOG	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several computers and computer types	Designed especially for the handling of symbolic computation and logic programming such as the creation of simple databases	

FULL NAME	ACRONYM	LANGUAGE TYPE
Remote User Shared Hardware	RUSH	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Unknown		

FULL NAME	ACRONYM	LANGUAGE TYPE
SIMSCRIPT	SIMSCRIPT	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several mainframe computers		

FULL NAME	ACRONYM	LANGUAGE TYPE
SKOOLBOL	SKOOLBOL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Digital PDP-7 computer		

FULL NAME	ACRONYM	LANGUAGE TYPE
SMALLTALK	SMALLTALK	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Xerox Dynabook computer	Experimental version intended for a hand-held computer; claimed by some to have led to graphical user interfaces	

FULL NAME	ACRONYM	LANGUAGE TYPE
SOLO	SOLO	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Several computers and computer types	Based on LOGO and designed for psychology students; contains automatic aids and special help functions	

FULL NAME	ACRONYM	LANGUAGE TYPE
SPITBOL	SPITBOL	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Several mainframe computers	A variation of SNOBOL	

FULL NAME	ACRONYM	LANGUAGE TYPE
StriNg Oriented symBOLic language	SNOBOL	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Several mainframe computers	A string manipulation language	

FULL NAME	ACRONYM	LANGUAGE TYPE
Student COntrolled On-line Programming	SCOOP	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Single unknown mainframe	British-designed language; development limited by high cost of required interactive terminals	

FULL NAME	ACRONYM	LANGUAGE TYPE
STRINGCOMP	STRINGCOMP	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Some Digital Equipment mainframe computes		

FULL NAME	ACRONYM	LANGUAGE TYPE
TELCOMP	TELCOMP	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Some Digital Equipment mainframe computes		

FULL NAME	ACRONYM	LANGUAGE TYPE
Teacher Student Algol	TSA	PROGRAMMING
COMPUTER OR SYSTEM	**COMMENTS**	
Digital PDP-1 computer		

FULL NAME	ACRONYM	LANGUAGE TYPE
Teletype INTerpreter	TINT	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Unknown		

FULL NAME	ACRONYM	LANGUAGE TYPE
Univac Interactive Language	UIL	PROGRAMMING
COMPUTER OR SYSTEM	COMMENTS	
Several Univac computers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Creative Course Writer	CCW	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers; also requires IBM 3270 series mainframe computer	Designed to convert microcomputer-generated word processing files into PILOT for microcomputer use and COURSEWRITER for mainframe use	

FULL NAME	ACRONYM	LANGUAGE TYPE
EASYWRITER	EASYWRITER	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several microcomputers	Written in BASIC; prompt-driven; generates dialect of PILOT code	

FULL NAME	ACRONYM	LANGUAGE TYPE
eXperimental Authoring System, also known as YUKKY	XAS or YUKKY	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Some VAX computers	Written in E.L.F.; generates Coursewriter II code; interactive with menu of commands	

FULL NAME	ACRONYM	LANGUAGE TYPE
OMNISIM	OMNISIM	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Some PLATO versions	Generates TUTOR code	

FULL NAME	ACRONYM	LANGUAGE TYPE
Simple Author Language	SAL	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Some minicomputers	Interactive dialogue with prompts; generates BASIC code; designed to accommodate the control of audio-visual output peripherals	

FULL NAME	ACRONYM	LANGUAGE TYPE
Science Teachers Authoring Facility	STAF	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Low-level authoring system developed in the United Kingdom; two main versions, one produces BASIC code, the other FORTRAN	

FULL NAME	ACRONYM	LANGUAGE TYPE
TA program generator for tencore	TA	FRONT END AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers	Creates lessons in TenCORE language	

FULL NAME	ACRONYM	LANGUAGE TYPE
ADAPT	ADAPT	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several types of microcomputer	MicroTICCIT system	

FULL NAME	ACRONYM	LANGUAGE TYPE
Advanced Instructional System II	AIS II	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several minicomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Applied Data Research/Personal Computer ADROIT	ADR/PC ADROIT	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
ASAP!	ASAP!	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers		

FULL NAME A Tutorial System	ACRONYM ATS	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Some mainframe computers	COMMENTS	

FULL NAME Audio Enhanced Computer Assisted Learning authoring language	ACRONYM AECAL	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Unknown	COMMENTS Constructed using BASIC	

FULL NAME Author Command Language	ACRONYM ACL	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Several computer types	COMMENTS Designed for preparing instructional materials for keyboard training	

FULL NAME Author Language for Laser Vision Applications	ACRONYM ALLVA	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Some Philips computers	COMMENTS A graphics authoring language for larger systems, such as PHILVAS (PHilips Laser Vision Authoring System)	

FULL NAME Author System for Education and Training	ACRONYM ASET	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Sperry Univac 1100 series computers	COMMENTS	

FULL NAME Authority	ACRONYM AUTHORITY	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM PC & MS DOS-based microcomputers	COMMENTS Menu-driven commands	

FULL NAME Authorware Professional, also known as Course of Action	ACRONYM AP or COA	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Macintosh and DOS-type microcomputers	COMMENTS Icon-based programming system	

FULL NAME	ACRONYM	LANGUAGE TYPE
AutoMentor	AUTOMENTOR	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Avid	AVID	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several minicomputers and microcomputers	Provides prompts for incomplete frames	

FULL NAME	ACRONYM	LANGUAGE TYPE
CAT/S	CAT/S	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers	Menu-driven commands	

FULL NAME	ACRONYM	LANGUAGE TYPE
CEIT LESSON AUTHOR	CEIT LESSON AUTHOR	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers	Written in C language to enhance potential portability to other computers	

FULL NAME	ACRONYM	LANGUAGE TYPE
CHIMP	CHIMP	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Univac model 1108 mainframe computer		

FULL NAME	ACRONYM	LANGUAGE TYPE
Completely Arbitrary Name	CAN	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Developed at the Ontario Institute for Studies in Education	

FULL NAME	ACRONYM	LANGUAGE TYPE
Completely Arbitrary Name (version) 8 Course Authoring Language	CAN-8 CAL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
CAN-8 Honeywell minicomputer	Low-level authoring language requiring some knowledge of programming; derived from CAN	

FULL NAME	ACRONYM	LANGUAGE PE
COACH	COACH	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several types of computers	Based on BASIC; uses 15 key words for commands	

FULL NAME	ACRONYM	LANGUAGE PE
Computer Assisted/Managed Instructional Language	CAMIL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Unknown	Developed and used primarily by the U States Air Force	

FULL NAME	ACRONYM	LANGUAGE PE
Computer Assisted Self Training	CAST	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Microcomputers running UNIX operating system	Based on PILOT	

FULL NAME	ACRONYM	LANGUAGE PE
Computer Assisted Student Tutorial Learning Environment	CASTLE	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Commodore CBM 8096 microcomputer	Written in COMOL	

FULL NAME	ACRONYM	LANGUAGE PE
Computer-Based Training Systems-Computer Managed Learning	CBTS-CML	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several VAX computers		

FULL NAME	ACRONYM	LANGUAGE PE
COMPUter language for individual TESTing	COMPUTEST	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
IBM 360 and SDS 940 mainframe computers	Exam writing; precursor to PILOT	

FULL NAME	ACRONYM	LANGUAGE PE
Computer-Oriented Programmed Instruction	COPI	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Unknown	Two versions are noted	

FULL NAME Computer Systems Research Trainer-4000	ACRONYM CSR T-4000	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM DOS-type microcomputers	COMMENTS Largely menu-driven	

FULL NAME Computerized Lesson Authoring System	ACRONYM CLAS	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM DOS-type microcomputers	COMMENTS	

FULL NAME Concurrent Authoring System	ACRONYM CAS	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM DOS-type microcomputers and Vasco Concurrent mainframe computers	COMMENTS Hybrid micro-mainframe system; microcomputers are connected to a mainframe and operate both as local processors and as dumb terminals	

FULL NAME Course Assembly System and Tutorial Environment	ACRONYM CASTE	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Several minicomputers and microcomputers	COMMENTS Written in MicroSoft Basic	

FULL NAME Course Author Language	ACRONYM CAL	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Unknown	COMMENTS	

FULL NAME CourseMaster (American Industrial Publications)	ACRONYM CM	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM DOS-type microcomputers	COMMENTS Can use prepared courseware templates	

FULL NAME	ACRONYM	LANGUAGE TYPE
CourseMaster (InterDigital)	CM	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type and some Wang microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
CICERO	CICERO	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Unknown mainframe computer	Developed by the Open University in London; intended for designing programs for distance learning	

FULL NAME	ACRONYM	LANGUAGE TYPE
Computer Modular Exercise Templates	COMET	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several microcomputers	Designed in BASIC; can generate foreign characters by adding a special EPROM to the microcomputer	

FULL NAME	ACRONYM	LANGUAGE TYPE
COURSEWRITER I	CW I	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
IBM 1440 mainframe computer	Original version	

FULL NAME	ACRONYM	LANGUAGE TYPE
COURSEWRITER II	CW II	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
IBM 1500 system and Digital PDP 8 computer	Enables CRT, audio and projector control	

FULL NAME	ACRONYM	LANGUAGE TYPE
COURSEWRITER III	CW III	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
IBM 360 mainframe computer		

FULL NAME	ACRONYM	LANGUAGE TYPE
CourseWriter	CW	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
CREATE	CREATE	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Menu-driven; part of the Top Class instructional/presentation system

FULL NAME	ACRONYM	LANGUAGE TYPE
DIALOG	DIALOG	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Technomonics 6700 system; some IBM mainframe computers and DOS-type microcomputers	Conversational style; can use a light pen; recent versions written in PASCAL are menu driven

FULL NAME	ACRONYM	LANGUAGE TYPE
Digital Equipment Company Authoring Language	DECAL	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
PDP 11 minicomputer	Similar to TUTOR, but much more structured; written in BASIC with REGIS language for graphics

FULL NAME	ACRONYM	LANGUAGE TYPE
DITCH	DITCH	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Unknown	

FULL NAME	ACRONYM	LANGUAGE TYPE
DOMINO	DOMINO	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Graphics and text capabilities; can support light pens, mice, graphics tablets

FULL NAME	ACRONYM	LANGUAGE TYPE
EASE	EASE	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	A high-level language designed specifically for the PHOENIX presentation system

FULL NAME	ACRONYM	LANGUAGE TYPE
EASY	EASY	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Template-based using plain language prompts; high-level

FULL NAME	ACRONYM	LANGUAGE TYPE
Educational Technology Language	ETL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Some mainframe computers	Developed in the United Kingdom	

FULL NAME	ACRONYM	LANGUAGE TYPE
Educator's Automated Authoring SYstem	EAASY	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
CAN-8 Honeywell minicomputer	High-level language	

FULL NAME	ACRONYM	LANGUAGE TYPE
ELIZA	ELIZA	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	For natural language-like instruction in Artificial Intelligence contexts	

FULL NAME	ACRONYM	LANGUAGE TYPE
EXEMPLAR	EXEMPLAR	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers	Menu-driven with dynamic menus (display valid selections only)	

FULL NAME	ACRONYM	LANGUAGE TYPE
First Oise Cai Author Language	FOCAL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several computer types	Developed at the Ontario Institute for Studies in Education; no connection with FOCAL programming language	

FULL NAME	ACRONYM	LANGUAGE TYPE
GLURP	GLURP	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Unknown	Based on MINORCA	

FULL NAME	ACRONYM	LANGUAGE TYPE
Honeywell Author Language	HAL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Honeywell series 200 computers	Similar in nature to Coursewriter	

FULL NAME	ACRONYM	LANGUAGE TYPE
IDF	IDF	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Unknown	Designed by Hewlett-Packard	

FULL NAME	ACRONYM	LANGUAGE TYPE
IMAGES II	IMAGES II	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers	Menu-driven; customized menus possible	

FULL NAME	ACRONYM	LANGUAGE TYPE
Improved Authoring Language	IAL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Some mainframe computers		

FULL NAME	ACRONYM	LANGUAGE TYPE
INFOWRITER	INFOWRITER	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers	Menu-driven	

FULL NAME	ACRONYM	LANGUAGE TYPE
Instructional Programs of considerable Sophistication	IPS	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
IBM 370 mainframe computer	Written in SPITBOL; attempts to combine desirable features of Coursewriter and TUTOR	

FULL NAME	ACRONYM	LANGUAGE TYPE
Instructional WorkBench	IWB	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Computers using Unix System V operating system		

FULL NAME	ACRONYM	LANGUAGE TYPE
INTERACtive Training program	INTERACT	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
DOS-type microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Interactive Movie System	IMS	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
Several types of microcomputers	Author may customize templates	

FULL NAME Interactive Video Learning	ACRONYM IVL	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Apple II series microcomputers	COMMENTS High-level, plain language prompt-driven; can incorporate programs written in BASIC	

FULL NAME KSS:AUTHOR	ACRONYM KSS:AUTHOR	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Several computer types	COMMENTS Can be customized for many operating systems	

FULL NAME Language for Your Remote Instruction by Computer	ACRONYM LYRIC	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Several computer types	COMMENTS A pre-processor to a FORTRAN compiler; designed for the MAESTRO system (Machine-Assisted Educational System for Teaching by Remote Operation)	

FULL NAME Lernen Im DIAlog (Learning In Dialog)	ACRONYM LIDIA	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Siemens 4004/45 computers	COMMENTS German developed authoring language	

FULL NAME Logitexte	ACRONYM LOGITEXTE	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM Several computer types	COMMENTS Developed in Québec; French authoring language	

FULL NAME MASTWRITER	ACRONYM MASTWRITER	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM DOS-type microcomputers	COMMENTS Menu-driven; designed to control peripheral presentation devices such as projectors; developed by MAST Learning Systems (manufactured a lineof teaching machines)	

FULL NAME MATHLAB	ACRONYM MATHLAB	LANGUAGE TYPE AUTHORING
COMPUTER OR SYSTEM PDP-6 computer	COMMENTS	

FULL NAME	ACRONYM	LANGUAGE TYPE
McGraw-Hill Interactive Authoring System	MCGRAW-HILL (IAS)	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	High-level authoring primarily

FULL NAME	ACRONYM	LANGUAGE TYPE
MENTOR	MENTOR	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Several microcomputers	Uses a LISP compiler

FULL NAME	ACRONYM	LANGUAGE TYPE
MicroInstructor	MICROINSTRUC-TOR	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Several microcomputers	Built-in operating system; prepared and customized templates

FULL NAME	ACRONYM	LANGUAGE TYPE
MICROTEXT	MICROTEXT	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Several microcomputers	Frame-based; 4 basic authoring modes, command, edit, text and run; developed in the United Kingdom

FULL NAME	ACRONYM	LANGUAGE TYPE
MINORCA	MINORCA	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Unknown	

FULL NAME	ACRONYM	LANGUAGE TYPE
MR. Computer	MRC	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Honeywell and Univac computers	Written in ALGOL and FORTRAN

FULL NAME	ACRONYM	LANGUAGE TYPE
Mr. Ed Authoring Software	MEAS	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	User-designed templates

FULL NAME	ACRONYM	LANGUAGE TYPE
MUlti MEDia Authoring LAnguage	MUMEDALA	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Special mainframe computers	Designed to use light pens, projectors, tape recorders and videodisks

FULL NAME	ACRONYM	LANGUAGE TYPE
MUSIC	MUSIC	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Unknown	

FULL NAME	ACRONYM	LANGUAGE TYPE
NATional Author Language	NATAL	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Several computer types	National Research Council of Canada's attempt at a standard language for Computer Assisted Instruction

FULL NAME	ACRONYM	LANGUAGE TYPE
OF COURSE!	OC	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Burroughs B25 running Convergent Technologies Operating System Version 9.0 or later	Possesses capability for voice generation

FULL NAME	ACRONYM	LANGUAGE TYPE
Perdue Interactive Computer-aided Learning System	PICLS	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Unknown	

FULL NAME	ACRONYM	LANGUAGE TYPE
Phoenix	PHOENIX	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Several computers	

FULL NAME	ACRONYM	LANGUAGE TYPE
Primary Author's Language	PAL	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Some mainframe computers	

FULL NAME	ACRONYM	LANGUAGE TYPE
Professional Authoring Software System	PASS	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Apple II series microcomputers	Marketed by Bell & Howell; intended for multi-media presentations primarily	

FULL NAME	ACRONYM	LANGUAGE TYPE
Programmed Inquiry, Learning Or Teaching	PILOT	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Several computer types	Different versions for different machines	

FULL NAME	ACRONYM	LANGUAGE TYPE
Programming LANguage for Interactive Teaching	PLANIT	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
SDC Q-32 computer	Written in JOVIAL	

FULL NAME	ACRONYM	LANGUAGE TYPE
Prophit Mentor	PM	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
DOS-type microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Quest	QUEST	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Several microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
Regency 2-C	R2-C	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
microcomputers using the Regency USE operating system		

FULL NAME	ACRONYM	LANGUAGE TYPE
SAM	SAM	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
DOS-type microcomputers		

FULL NAME	ACRONYM	LANGUAGE TYPE
SCHOLAR/TEACH	SCHOLAR/TEACH	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Designed by Digital Equipment Company; marketed by Boeing Computer Services

FULL NAME	ACRONYM	LANGUAGE TYPE
Shelley	SHELLEY	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Three authoring modes: menu-driven; text authoring; and programming

FULL NAME	ACRONYM	LANGUAGE TYPE
Taiga	TAIGA	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	

FULL NAME	ACRONYM	LANGUAGE TYPE
Teachers Aide	TEACHERS AIDE	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Prompting through pop-up menus

FULL NAME	ACRONYM	LANGUAGE TYPE
TenCORE	TENCORE	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Microcomputer version of TUTOR used with PLATO

FULL NAME	ACRONYM	LANGUAGE TYPE
TES/T	TES/T	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Unknown	Menu-driven

FULL NAME	ACRONYM	LANGUAGE TYPE
The AUTHOR	THE AUTHOR	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type and Apple II microcomputers	Bbranching complexity of lessons is limited by available diskette storage space

FULL NAME	ACRONYM	LANGUAGE TYPE
The Educator	THE EDUCATOR	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type and UNIX-based microcomputers	Templates in the form of pre-formatted menus

FULL NAME	ACRONYM	LANGUAGE TYPE
The Instructor	THE INSTRUCTOR	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Apple II series microcomputers	Page templates with prompting commands

FULL NAME	ACRONYM	LANGUAGE TYPE
TICCIT Author Language	TAL	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Hazeltine and Data General mini + computers, and DOS-type microcomputers	

FULL NAME	ACRONYM	LANGUAGE TYPE
TUTOR	TUTOR	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Some PLATO systems	

FULL NAME	ACRONYM	LANGUAGE TYPE
Unison Author Language	UAL	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
DOS-type microcomputers	Based on TUTOR

FULL NAME	ACRONYM	LANGUAGE TYPE
Univac Author Language	UAL	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
Several Univac computers	

FULL NAME	ACRONYM	LANGUAGE TYPE
Urbana Software Enterprises	USE	AUTHORING

COMPUTER OR SYSTEM	COMMENTS
PLATO V	Dialect of TUTOR; designed for local editing on terminals with a microprocessor

FULL NAME	ACRONYM	LANGUAGE TYPE
VAX Producer	VAX PRODUCER	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Several VAX computers	Icon-oriented editor	

FULL NAME	ACRONYM	LANGUAGE TYPE
Versatile AUthoring Language for Teachers	VAULT	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
IBM 1500 system, and IBM 360 mainframe computer	Developed at the University of Alberta; creates COURSEWRITER II code	

FULL NAME	ACRONYM	LANGUAGE TYPE
Video Nova Authoring System	VNAS	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Several microcomputers	Facility for creating lessons using Arabic fonts	

FULL NAME	ACRONYM	LANGUAGE TYPE
Voice Oriented Curriculum Author Language	VOCAL	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Several mainframe computers	Based on LISP	

FULL NAME	ACRONYM	LANGUAGE TYPE
VS Author	VS AUTHOR	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
Wang VS-type computers	Menu-driven	

FULL NAME	ACRONYM	LANGUAGE TYPE
Wicat Interactive System for Education	WISE	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
WICAT (World Institute for Computer Assisted Training) computers	High-level, menu-driven; a component of SMART (System for Managing Authors, Resources, and Training)	

FULL NAME	ACRONYM	LANGUAGE TYPE
WRITEACOURSE	WRITEACOURSE	AUTHORING
COMPUTER OR SYSTEM	**COMMENTS**	
IBM 360 and Burroughs B5500 mainframe computers	Based on ALGOL	

FULL NAME	ACRONYM	LANGUAGE TYPE
XCAL	XCAL	AUTHORING
COMPUTER OR SYSTEM	COMMENTS	
PC DOS-type microcomputers	Designed for creation of display screens with textual and graphic information	