University of Alberta

Didactic versus heuristic approaches to learner control in computer-assisted instruction

by

Karla Blonsky ©

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Abstract

Research in computer-assisted instruction (CAI) has focussed on the effectiveness of different design features; one such feature, learner control, has been examined extensively, While several generalizations on the value of this feature have been identified in the literature, they have been qualified by the context for each study. Internal variables, such as the degree or nature of the learner control, as well as external factors including learner characteristics and environmental influences, have been identified as significantly impacting learner control effectiveness. In this study, two levels of learner control over review of background material were examined with external influences of learner academic standing, topic, and order of exposure also considered.

This research involved three treatment groups who viewed a two unit CAI lesson, where one group viewed CAI with high levels of learner control followed by low levels, a second viewed low levels followed by high, and the third acted as a control, receiving no CAI. Pre- and post-test scores were analyzed separately for each unit to identify treatment effects. When post-scores alone were used, a single between-treatment group difference was detected in the second unit favoring high levels of learner control over the control; however, once the pre-test scores were included as the covariate, no significant differences were detected. When learner academic standing was incorporated in the analysis, a significant interaction between learner control level and academic standing was detected in the second unit. No interaction was detected in the first unit, although significant differences were identified based on academic standing alone.

The results obtained varied depending on the unit being examined, the external factors which were included in the analysis, and the measure of achievement utilized, all of which reinforced the importance of contextual consideration when examining the research. The nature of the learner control provided in this study, the degree of guidance

for optional access, and the integration of each review section coincidental with the examples all defined the structural setting and qualified generalization to other environments. Differences in the results between the two units suggested external factors such as order of exposure to learner control, topic complexity, and learner fatigue may have influenced the learner control effect. The interaction with learner academic standing supported previous research which suggested that a certain level of sophisticaton or achievement was required for learners to obtain substantial benefit from learner control; poorer students performed better when given less control. A need for additional research in identification of factors which define the context for learner control studies and limit the generalization of findings between such studies was suggested.

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Chapter I

Overview of the Problem

Introduction

The massive infusion of computers in education since their introduction in the mid-1960's has resulted in a "recontextualization of learning" (Riel, 1989, p.188), where instructional technology is no longer viewed as a peripheral tool but as an essential part of instruction. This recontextualization has been described as the "revolutionization of our historic notions of teaching and learning" (Hannafin, 1992, p.50) and the "wholesale restructuring of education" (Riel, 1989, p.180) in a continuing process of development of new systems, programs and features in computer-assisted instruction (CAI). This transformation of learning has long been reflected in the research, where enormous efforts to identify and maximize the benefits of CAI have been maintained over the past three decades. Today, virtually universal access to CAI and recent advances in computer technology have resulted in renewed interest in characterization of effective CAI.

The importance of development of high quality CAI cannot be understated, as the magnitude of computer use in instruction continues to develop at an astronomical rate. Computers were introduced relatively recently, with mainframes first having siginificant use in the 1960's and microcomputers appearing a decade later. Yet by the mid 1980's, computers were estimated to be used in some form of instruction in 83% of secondary schools and in over 80% of colleges and universities (Riccobono, 1986). By 1987, it was estimated that 90% of all schools in America employed computers in some form of instruction (Swan & Mitrani 1993) and by 1991, that figure had risen to 100% with corresponding increases seen in other countries (Pelgrum & Plomp, 1991). The financial investment in this resource is also indicative of the magnitude of computer use in education, with over $1 billion dollars spent on each of computer hardware and software in the United States during the 1993-94 year (CCA Consulting, 1994).

Students are now being exposed to computers at every level of formal and nonformal education in a wider range of applications than had ever been seen previously; however, this exposure to computers does not necessarily translate directly into exposure to computer-assisted instruction (CAI). Word processing, programming, data and graphic manipulation, and testing are other common student uses for the computers (Bork, 1990; Pelgrum & Plomp, 1991; Riel, 1989), with word processing being the dominant use (Becker, 1991; Riel, 1989). While 87% of computer-using teachers employed some form of CAI (Riel, 1989), the degree to which these instructors used this technology varied considerably. Only 58% of instructors reported consistent use of the computer throughout the year, with CAI comprising only a fraction of that use (Becker, 1991). The low use of this instructional media relative to the investment in the technology creates the huge potential for expansion of the role of CAI, as an ever-increasing number of instructors capitalize on these resources and integrate computers into their instruction (Pelgrum & Plomp, 1991)

Along with the increase in use, CAI has taken on new importance in instruction as the power and flexibility available in the different systems and programs has grown. New possibilities for the incorporation of computers into instruction are constantly being created as increased memory and processing speed becomes readily available in the hardware. The developments in hypermedia and the abilities of the software to incorporate such features as animation, movies, audio and digitized images have also resulted in drastic changes in the nature of the CAI used as existing options are expanded and previously unavailable features are created. As well, a shift toward authoring systems which are more user-friendly has augmented instructors' abilities to develop and/or tailor CAI programs for the specific needs of their particular classsrooms. However, with the increased flexibility and power of the computers comes the issue of how to obtain the maximum benefit from these new systems and programs. While this is not a new concern, it deserves renewed attention to meet the demands set by the advanced capabilities of current CAI; previous research using less sophisticated systems may no longer be applicable or relevant, potentially underestimating the effectiveness of contemporary CAI or misdiagnosing the characteristics which represent high quality courseware. To this end, the previous findings of research in effective CAI must be assessed in their context and not directly applied to the computer systems and programs currently in use.

Despite the extensive research previously carried out with respect to CAI, no generalizable consensus has been reached on the value of computers in the classroom or on the factors characteristic of effective programs (Clark, 1985; Colorado, 1988; Kulik, Kulik, & Cohen, 1980; Kulik, Kulik & Shwalb, 1986; Niemiec & Walberg, 1987). Design variables such as color, graphics and animation (Baek & Layne, 1988) have been the focus of much of this research. According to Merrill (1987), the lack of knowledge about design factors has significantly impaired the potential impact of instructional computer usage. The identification and removal of design flaws is essential to development of high quality programs and is of great concern as additional features and new ways of employing existing features are constantly being developed.

One design variable, learner control, has previously received considerable attention. However, the research has been cited as "producing equivocal results in the area of student achievement," (Kinzie, Sullivan, & Berdel, 1992, p. 101) "providing conflicting guidance" (Gray, 1989, p.459) and "as with most complex issues, generalizations regarding basic conclusions [have been] difficult to come by" (Duchastel, 1986, p.380). The conflicting evidence has been attributed to a range of confounding factors which influence the impact of learner control, including the degree of learner control employed, the sophistication of the learners involved, and the nature of the lesson developed. Learner control is seen as a relative concept along a continuum (Duchastel, 1986; Milheim & Martin, 1991), ranging from minor control over pacing or sequencing to student-centered programs where emphasis is placed on the learner's ability to control the direction and content of the lesson. This extreme range of uses of learner control necessarily compromises the generalizability of the value of learner control across studies. In addition, the sophistication of learners has been shown to impact the effectiveness of learner control: poorer learners have been shown to work better under program control, making few and poor choices under learner control; in contrast, skilled learners choose more options and learn equally as well or better under learner control (Goetzfried & Hannafin, 1985). Hannafin (1984) also indicated that certain characteristics inherent to a type of lesson influenced whether program or learner control was more effective and appropriate for that given program. Given these complex influences and the increased emphasis on learner-focused instruction, a need for much more data to produce a complete understanding of this variable has been identified (Kinzie et al, 1992; Milheim & Martin, 1991; Steinberg, 1989).

Problem Statement and Research Questions

This study assesses the effectiveness of CAI in an undergraduate genetics laboratory setting and analyzes the influence of learner control over presentation of remedial and support material on this effectiveness. As well, it seeks to determine the extent to which the effect of learner control is related to academic achievement of the learner. A comparison was made between academic achievement of students receiving traditional instruction alone, and traditional instruction plus CAI in one of two forms: (a) a CAI program with a low level of learner control, where a review of basic concepts was required to be completed before the learner proceeded with the lesson; and (b) a more heuristic program with a high level of learner control, where the learner diagnosed his/her own needs for basic background information.

The setting was an introductory undergraduate genetics course offered at the University of Alberta, where students had a wide range of concept understanding and CAI was not previously available. The CAI presented a framework for the analysis of monohybrid and dihybrid crosses emphasizing the underlying genetic causes of observed phenotypic distributions.

Several research questions were generated in the comparison of the formats:

1. Is there any difference between the achievement of students receiving CAI in each of the two formats in addition to the traditional instruction and that of students receiving only traditional instruction?

While the first question relates to the general nature of the CAI as compared to traditional instruction, it does not examine the influence of the design factor, learner control, on the effectiveness of that CAI. This leads to the second research question:

2. Is there any difference between the achievement of students receiving CAI designed with a low level of learner control and that of students receiving instruction with a high level of learner control?

A given level of learner control may not be appropriate in all contexts or for all students. The last research question examines the effect of learner sophistication as measured by academic standing on the impact of learner control:

3. Does the academic standing of the learners (i.e. low v. mid-range v. high achievers) have any influence on the effect of different levels of learner control?

Statement of Significance

This study will examine the effect of different levels of learner control over presentation of support material and remedial information for two CAI lessons. If it can be established that the degree of learner control has significant impact on the effectiveness of the CAI, this research will provide another step toward determination of what defines effective CAI courseware. This information in turn could be used to increase the benefit which could be achieved from the use of computers in instruction, maximizing their "educational usefulness" (Schaefermeyer, 1990, p.14). Only by identifying the characteristics of quality CAI in the reseach can computerized instruction reach its full potential and the lessons best be utilized in practice (Blum Cohen, 1983; Merrill, 1987). In addition, the identification of the impact of learner control in this study helps to sort out the confusion surrounding reseach dealing with this variable.

Clarification of the relationship between learner control effect and academic standing of learners is the second significant point of this study. Each study which examines learner control over different aspects of a lesson and in different settings further defines both the value and the appropriateness of learner control for specific contexts. The significance of this study is correspondingly defined within this context:

1. The two formats differ in the degree of learner control over the support material and remedial information presented; however, program control over the problem solving strategies is maintained.

2. The differences in learner control are limited to specific prescribed areas of the lesson where such information on problem solving strategies is required, rather than as a constant throughout the lesson.

3. The study is done in a genetics lesson on problem solving framework for simple Mendelian analysis, a higher order concept.

If the effectiveness of learner control is shown to be related to academic standing of the learner in the context of this study, it could support previous studies done in other contexts which indicated that poorer students tended to do better with more program control and higher achievers did better with learner control. By identifying features which are common to this study and those where such a relationship was seen, but which are different from those studies where no relationship was seen between effect of learner control and academic standing of the learners, the generalizability of findings dealing with learner control could be further identified. Accommodation of the range of learners in a specific audience of a lesson may serve to increase the individualized effectiveness of any CAI. Conversely, if no significant relationship is seen between the impact of learner control and the academic standing of the learners, examination of the features which differentiate this study from those where a relationship was identified could also aid in the determination of the generalizability of such studies.

Delimitations

1. The students used in the research represent a convenient volunteer sample drawn from the larger course population. While attempts have been made to assess the degree to which the sample is representative of the larger population, the scope of this study limits the number of variables which could be examined to this end. However, for analytical purposes, it was assumed that a representative sample had been used.

2. The focus of this research was on a single design variable, learner control over remedial and support information, and its relationship to academic standing of the learners. Therefore, analysis of results according to other student variables was not done as such further study was outside the scope of this research. Demographic data collected on the students were used to assess the representativeness of the sample, but were not used for analysis of the effect of learner control.

3. This research included data from students in the genetics course from a single term only. Time constraints prevented the inclusion of results collected from different terms over a greater time period.

Limitations

1. Because the use of CAI in this study was the first time computers were used in this setting, there is a possibility that a novelty effect was seen. This could result in over-estimation of the benefits of CAI.

2. The use of a convenient sample may result in bias of the results if the volunteers who were willing to participate in this study were not representative of the larger population. Attempts have been made to determine the extent to which this was

significant, but not all participant variables were able to be examined due to the limited scope of this research.

3. The CAI used in this study was developed specifically for the course by the researcher and was a first draft of the program. Although the CAI was pilot-tested under stringent conditions, the revision and optimization characteristic of long term implementation were not available. The results, therefore, may underestimate the effectiveness of the CAI.

Definition of Terms

Computer-assisted instruction — An instructional medium; any computer-delivered instruction which possesses elements of individualization, interactivity and guidance.

High quality software— Software that effectively provides individualized, interactive instruction

Effective instruction— instruction which promotes increased learning outcomes, such as improved academic achievement or affective response by the learners

Didactic instruction— a rigid method of teaching which is concerned with the imparting of facts in a directed fashion

Heuristic instruction— a method of teaching which focuses on discovery and encourages the learner to diagnose and apply strategies to facilitate his/her own learning

Learner control— a mode of instruction where the student has the ability to choose between options for a number of different parameters involved in learning, such as pacing, sequencing, or difficulty of information presented;

Program control—a mode of CAI where the programmer defines the parameters involved in learning and the student is given no choice as to the manner in which the instruction proceeds;

Traditional instruction— a delivery method where the content, sequence and pace of instruction are controlled; in the context of this research, non-CAI, lecture- and laboratory-based instruction.

Chapter II

Review of the Literature

Introduction

This literature review dealing with effective computer-assisted instruction (CAI) is divided into four sections. The first section describes the use of computers in instruction, with concentration on the role of computers in CAI. The second section discusses issues in computer-assisted instruction through examination of the status of research in CAI development. The third section depicts characteristics and features found to be indicative of effective CAI from practical and theoretical perspectives. The fourth section discusses one feature, learner control, as it relates to effective CAI.

Section 1: Use of Computers in Instruction

Education at all levels has been transformed by the "massive infusion" (Swan & Mitrani, 1993, p. 40) of computers into the classroom. "No other technology has been as dominant in changing the contours of education" (Niemiec & Walberg, 1987, p.19), revolutionizing instruction in such a universal and comprehensive manner. The impact of this technology has been felt in a wide range of settings as computer usage is now seen in levels of education ranging from primary schools to graduate programs and in a variety of forms of instruction spanning from formal public institutional contexts to self-directed, nonformal studies. While neither universal in nature nor uniform across all forms of instruction, computer use in instruction has had an enormous impact and is now an integral part of education as a whole.

Both the numbers and uses of computers have increased rapidly since the introduction of this technology in the mid-1960's. Initially, bulky mainframe computers were used, followed by smaller, more affordable and individualized minis and microcomputers which were developed in the following decades. By 1985, more than 90% of colleges and universities in a survey of 2830 American institutions had computers available for instruction (Riccobono, 1986). By 1989, this figure had increased to 98% of American schools at all levels (Pelgrum & Plomp, 1991). Today, virtually all schools, colleges and universities in Canada and the United States possess computers for their use in instruction (Swan & Mitrani, 1993).

The majority of statistics on computer use in the classroom have been generated from studies dealing with primary and secondary schools; information on post-secondary use of computers in instruction has been more limited and studies at this level tend to be done on smaller scales, using more restricted topics and fewer students. However, Ely

(1991) indicated computers were nearly universally available for instructional purposes in public post-secondary institutions in the United States, and evidence indicates a similar level is present in Canada, based on the essentially equivalent incorporation of computers in lower levels of schooling between the two countries (Pelgrum & Plomp, 1991).

Worldwide statistics show more varied availability of computers in the classroom. Pelgrum & Plomp's study (1991) of international computer use indicated that the trends seen in North America are fairly common across borders, with increased availability of computers in all 19 countries examined in this study. As well, a majority of schools used computers for instruction in over 80% of the countries surveyed in this study. However, the frequency of use at different levels of education, as well as the types of instructional use for the computers, varied considerably between the countries examined. Most variation was attributed to the range of educational policies and the diverse economic environments in the countries examined. Overall, the numbers of computers used in instruction has been increasing both nationally and internationally and the importance being placed on computer use in instruction appears to be correspondingly growing.

The near universal presence of computers is deceiving, however, as the presence of computers in an institution does not necessarily translate into high accessibility for all students nor does it correspond to universal use of CAI. The ratio of computers to students in different institutions varies dramatically, depending on the extent of the investment in hardware. In Ely's study (1991), 96% of elementary and secondary schools had computers, but only half had sufficient resources to permit less than 30 students per computer. Four percent (4%) had greater than 90 students for each computer. Any potential benefit from CAI would be diluted in such a setting where the ratio was so large that each student was not guaranteed access and those who had access may have viewed the computer for only a short period. In Alberta, on the other hand, the access in public schools was approximately 17 students for each computer, indicating the great value put on the use of CAI and the considerable investment in the technology (Alberta Education, 1987). Given this range in ratios, a "substantial computer experience" (Becker, 1991, p.386) would not be equivalent across all schools nor would the interaction with computers necessarily be sufficient to permit more than a brief introduction to the computers themselves (Becker, 1991). The statistics on computer use must therefore be examined within the context of student access to the hardware and not overestimated in situations where only a small portion of the students have access or where students have access for only negligible amounts of time.

Similarily, the use being made of computers cannot be assumed to be a constant between institutions. Two schools with the same number of students and the same hardware would not necessarily use the computers at the same level for equivalent benefit. Research has shown that the presence of computers does not guarantee their use. For example, while 98% of institutions in Becker's study (1991) possessed computers, teachers who used the technology in their instruction were still a minority. Only 58% of those computer-using instructors cited consistent use of computers throughout the academic year. This underuse is also a severe problem in higher education, although opinion varies as to the degree of severity. In 1986, 80% of higher education instructors were estimated to be implementing computers into instruction into their classes (Riccobono, 1986), but more recent studies have questioned this statistic. Greene (1991) investigated the belief that faculty in higher education were slow to incorporate computers in their instruction. While nearly half of the instructors claimed to have integrated computers into their courses, only slightly more than 17% were shown to be using computers when actual computer lab log times were examined. When the results were e[illegible] respect to the topics for the CAI lessons, it was found that 91% of instructo[illegible]tive disciplines were using CAI, but those in more qualitative disciplines [illegible]atly underusing the technology. While the size of this study (only three institutions) may have biased the results and resulted in an underestimation of the use of CAI, the waste of the computer resources would be considerable even if the actual magnitude of underuse was a fraction of what was seen in this study.

A final, and perhaps most important, qualification which must be considered when examining the statistics on computer use in education is the role which the computers play in the classroom. The use of computers in the classroom does not necessarily translate into the use of computer-assisted instruction (CAI). For example, CAI as a supplement to or replacement for traditional instruction cannot be considered equivalent to wordprocessing and data manipulation using the computer nor is it equivalent to instruction on programming. Only 74% (Becker, 1991) to 89% (Riel, 1989) of computer-using teachers employ instructional software at all, and the majority of these instructors do so for only a small fraction of their total instruction (Becker, 1991; Greene, 1991; Williams & Brown, 1991). Word processing, rather than CAI, was identified as the domina[illegible]mputer use in the classroom today (Becker, 1991; Greene, 1991). The potential for CAI use is clearly much greater than current levels and, despite its increasing role, the technology remains a largely untapped resource in the schools.

The reasons for use or nonuse of CAI are not simple; the factors involved reflect issues in quality assurance for CAI, mechanisms for implementation, and effectiveness of alternative forms for delivery of instruction. On an international scope, economic environment and government policy play the greatest role in influencing computer use in the schools, with lack of hardware being the major impediment on a practical level (Pelgrum & Plomp, 1991). In North America, the use of computers in instruction is encouraged under government policy; the hardware and, to a large extent, software resources are in place; and, overall, the ratio of students to computers is better than other countries (Pelgrum & Plomp, 1991). Virtually 100% of students have access at some level to CAI. Programs such as the School Technology and Incentive Award Grants in Florida, the Centers for Development and Technology in Texas, and the American

National Goals 2000: Educate America Act are examples of the extensive support for increased acquisition and use of computers in education (Nelson B. Heller & Associates, 1994). In addition, corporations are playing a greater role as supporters of educational technology as evidenced by their funding of several recent projects including Pacific Bell's $600 000 donation for the purchase of more computer hardware in California (Nelson B. Heller & Associates, 1994). However, to date, the return for this investment in computer technology has been minimized by low and restricted use. Pelgrum & Plomp (1991) identified time constraints and a lack of software as major barriers to implementation of CAI on an international scale. Ely (1990, 1991) similarily identified both quantity and quality of software, time restrictions for instructors, hardware availability, lack of integration in the curriculum, and absence of adequate administrative support for the lack of computer use. In their study of home use of computers for instruction, Giacquinta, Bauer, & Levin (1993) cited insufficient knowledge/awareness, high cost of hardware and software, and low opinion of educational software quality as deterants for implementation of CAI. The issue of quality in the software, in particular, has received extensive attention in all areas of the research and is the focus of the following section of this literature review.

Not only the reasons for nonuse of CAI provide insight into the inclusion of computers in instruction; equally important are the motives for incorporation of computers in instruction. Academic improvement, student experience with technology for future activities, and individualization of instruction are often cited as motives for CAI use (Greene, 1991; Kulik et al, 1986; Merrill, 1987; Pelgrum & Plomp, 1991). In post-secondary education, motives identified for use of CAI were similar: the unique capabilities of the computer as an extension of instruction, the methods for adaptation of instruction, and the characteristics of the computer which were related to the specific subject matter (van Dijk, Gastemper, Moonen, & Romeijn, 1985). As well, the gradual redefining of the role of the teacher, the concept of the school, and the very nature of learning has produced a more learner-centered focus to instruction in recent years. The computer's ability to individualize instruction and to adapt to different learner needs has been cited as advantageous for heightening the degree of student-centered instruction (Swan & Mitrani, 1993) and has supported the incorporation of this technology into such an environment. Inspite of any possible benefits due to the particular attributes of new technology, its mere existence was insufficient for incorporation of that technology into instruction. The presence of dissatisfaction with the status quo or some other strong motive was required to justify the effort required to learn about the new technology and incorporate it in the classroom (Becker, 1991; Ely, 1991).

The need to improve the use of computers in instruction has become more evident as evidence mounts with respect to the gap between resource acquisition and technology usage.

> Software production and distribution (and even training in how to use software) is not nearly a sufficient condition for frequent and integral use, particularly when the software requires a new approach to teaching and learning subject-matter and is not just an analogical transformation of pen-and-pencil activities (Becker, 1991, p. 40).

However, there are signs that this deficiency in use is being remedied now that the attitudes, knowledge and hardware are in place. Pelgrum & Plomp (1991) identified a trend toward increased CAI use and decreased students numbers per computer worldwide. Locally, Greene (1991) identified an acceleration in the number of North American faculty incorporating CAI in higher education. The critical measure for integration of computers in education appeared to be the faculty's exposure time to CAI. In quantitative disciplines where computers had been used in instruction for several years, high use was already seen; more qualitative disciplines with faculty who had dealt with CAI for a shorter period only recently showed a dramatic increase in use of the technology. Greene identified a critical threshold of exposure time after computers first became available at work (between five and eight years) which was required before faculty began to integrate computers in their instruction. Now that the technological and instructional resources are in place and it appears that the threshold exposure time is being reached in more and more disciplines, knowledge of how best to obtain maximum benefit from CAI has become essential if the investment in this technology is not to be wasted.

Section 2: Research in Computer-assisted Instruction

In an attempt to maximize the return on the investment in computer-assisted instruction, considerable research has been generated in identificaton of the traits which are characteristic of effective CAI and the mechanisms by which computers can most productively be incorporated into the classroom. However, a large discrepancy between the theoretical knowledge base and the employment of this information in practical settings has limited progress in this area (Clark, 1985). The cause of this discrepancy, referred to by Ross as "a polarization between research and application that still prevades many of the older academic disciplines" (Ross, Sullivan, & Tennyson, 1992, p.5), is considered to be the insular nature of both the groups conducting research into effective CAI and those who are more concerned with its practical nature:

> Advances in computers and related hardware technology have far out-stripped prevailing design methodologies. The [practical side of the] field remains insulated from developments of considerable consequence for improving learning and isolated collectively from intellectual communities where significant work... has occurred (Hannafin, 1992, p.49).

The absence of application of research findings has the effect of eroding the potential return from the investment in computer technology and denies learners the full advantage of CAI; however, there are some signs that this rift between theory and application is mending. An increased "recognition of the need for consolidation [has led to greater] acceptance of the idea that application needs research and that research needs to be driven largely by variables and conditions applicable to improving the learning environment" (Ross et al, 1992, p.5).

The consolidation of research findings with practical implementation is often difficult to achieve as much of the research being done in CAI is highly contextual, with only restricted generalizability across settings.

> When it comes to computers in education, diversity defies description... The common thread is that virtually every student, teacher and administrator has computer access, but beyond that one similarity, all other aspects are different (Ely, 1991, p.18).

To find generalizable principles in the research requires identification of common features between different studies. However, the studies have involved a wide range of computer systems, CAI types, subject matters, and learners, with a correspondingly wide range of findings (Colorado, 1988). Williams & Brown (1991) argued that the context of studies as defined by the usage made of the technology was imperative to understanding the value of computers in instruction and attempts to over-simplify the factors involved has confounded the research.

> Compression of subgroups that differ in terms of the extent to which the computer is used as a substitute for traditional instruction into superclasses of computer-assisted versus conventionally taught groups has led to confusion in the interpretation of the effectiveness of the computer... (Williams & Brown, 1991, p.29).

The conditions under which the research has been carried out have also varied considerably. The quality of the CAI used has not been consistent between studies, nor have many of the variables which are known to affect the outcome of studies been identified (Williams & Brown, 1991). The complexity of the contexts for these studies has created much confusion and conflicting results in the research (Colorado, 1988). In turn, this confusion exacerbates the discrepancy between theory and application as those involved in the practical aspects of CAI lose faith in conflicting reports and shy away from the seemingly perplexing research results.

The confusion in the research can be attributed in large part to the lack of standard measures of the effectiveness of CAI. Computer-assisted instruction effects have been seen "to vary according to the evaluation design that was used to measure CAI effectiveness..." (Colorado, 1988, p.227). The criteria used to define effectiveness are diverse and complex in and of themselves, including such measures as academic achievement (Baek & Layne, 1988, Merrill, 1987; Rieber, 1991); long-term retention (Gray, 1988; Williams & Brown, 1991); attitude toward computers, subject matter, and instruction in general (Duin, 1988; Kinzie et al, 1992; Powell, 1987); instruction time (Murphy & Davidson, 1991; Schloss, Sindelar, Cartwright, & Smith, 1988); cost efficiency (Levin & Meister, 1986); and performance quality (Duin, 1988; Hannafin & Carney, 1991; Mory, 1992). The common element in the research into effectiveness is an attempt to measure whether the CAI achieved that which it set out to do, whether academically, motivationally or efficiently.

Overall, the incorporation of computers in instruction has generated either neutral or positive effects with all measures of effectiveness. Positive, although small, academic achievement gains were identified in several meta-analyses. The first major study (Kulik et al, 1980) reported average effect size gains of 0.51 for CAI over traditional forms of instruction. In later studies, this gain was slightly smaller, with effect size gains of 0.42 in a study of adult learners in nontraditional setting (Kulik, et al, 1985) and 0.4 in secondary schools (Bangert-Drowns, Kulik, & Kulik, 1985) . Niemiec and Walberg (1987) also reported a gain of an effect size of 0.42, with eighty-two (82%) of the studies examined favoring CAI. Retention of information over longer periods of time also showed positive gains with CAI (Williams & Brown, 1991).

The benefits of CAI were more markedly apparent when the technology was examined with respect to its unique capabilities to deliver instruction.

> Computer-based education offers the potential of consistent, high quality individualized instruction that is less vulnerable to the normal differences

> of teacher preparedness, school environment, peer pressure and teacher-student interaction (Merrill, 1987, p.18).

This consistency and patience of the computer, combined with the interactivity and individualization of instruction characteristic of CAI, is reflected in the positive affective responses to the technology. Attitude toward computers and toward instruction in general consistently showed positive gains when CAI was employed compared to traditional instruction (Bangert-Drowns & Kozma, 1989; Williams & Brown, 1991), although the results on attitude change toward subject matter were less consistent (Seymour, Sullivan, Story, & Mosley, 1987). Motivation improvement has been cited as one of the areas which holds the greatest potential for benefit from CAI (Kinzie et al, 1992). The use of computers has also been shown to reduce the time required to learn (Williams & Brown, 1991) and to be cost effective (Niemiec & Walberg, 1987; Williams & Brown, 1991).

These findings of the benefits of CAI have been generated in studies which concentrated on comparison of the "educational usefulness" (Schaefermeyer, 1990) of computers relative to other forms of instruction. (Emerson, 1988; Greene, 1991; Kulik et al, 1980; Kulik et al, 1986; Szabo & Montgomerie, 1992). However, evidence exists of confounding when comparison of CAI and traditional instruction was done without identification of specific characteristics to which the impact can be attributed (Clark, 1985).

> Comparative educational studies are plagued by the burning question: are the differences between groups due to the different instructional strategies of are they due to factors extraneous to the instructional strategies. Careful identification and elimination of these extraneous variables is essential to the validity of these studies (Emerson, 1988, p.48).

As a result of confounding by extraneous variables, arguments have been made that "achievement gains [due to the use of computers in instruction] are overestimated and are actually due to the uncontrolled but robust instructional methods embedded in CBI...

other media [may achieve] gains comparable to those reported for computers" (Clark, 1985, p.249).

To combat these concerns as to the validity and generalizabiltiy of research results, studies have been conducted into the specific features of CAI which may confound the studies. The computer's abilities to incorporate high levels of interactivity and deliver individualized instruction have been identified as major advantages of the use of the computer in instruction (Alessi & Trollip, 1991; Hodgson & Murphy, 1984; Kettinger, 1991). Yet without careful examination of these abilities, generalizations can not be made as to whether any gains seen in successful CAI programs were due to the use of the computer or to the interactive or individualized nature of the instruction. In order to control for these characteristics, Emerson (1988) examined academic achievement of students in a comparison of CAI with its non-computerized roots, socratic dialogue and programmed instruction, along with other instructional strategies. CAI strategies were shown to be superior to non-computer strategies only when interactivity was incorporated, yet interactivity alone was not a sufficient criterion for an instructional strategy to be considered successful (Emerson, 1988, p.49).

Other attempts have been made to control for confounding factors in CAI research. Two of the major causes cited for the overestimation of CAI benefit are the increased effort involved in preparation of CAI which produces higher quality instruction materials than traditional methods and the novelty effect associated with the use of innovative technology in the classroom. When these factors were controlled for in long term studies or with "same teacher" preparation of both CAI and alternate forms of instruction, benefits attributed to CAI were diminished, but still apparent (Clark, 1985). In a survey of the faculty of 28 different academic disciplines in four American colleges, no significant problems were identified which were attributable to student distraction from learning objectives due to the novelty of the new technology used in CAI, the second identified cause of overestimation. "...Any distraction (or other negative) effect [was] either temporary or more than offset by other [positive] factors of CAI" (Greene, 1991, p.43).

Another concern with the research is the reliance on comparative studies between CAI and other forms of instruction, where the assumption exists that the delivery system alone is responsible for any difference seen. A debate as to whether the medium alone was responsible for any instructional outcomes has been an ongoing focus of the research (Clark, 1994; Jonassen, Campbell & Davidson, 1994; Kozma, 1992). On the one hand, the computer has been described as a "synergistic combination of technology, task, and content" (Jonassen et al, 1994, p.31) and " not just another 'delivery system' but an environment that [has] certain values and biases associated with it" (Streibel, 1986, p. 137). Kozma (1991) felt that the "capabilities of a particular medium in conjunction with methods that take advantage of these capabilities, interact with and influence the ways learners represent and process information and may result in more or different learning when one medium is compared to another" (Kozma 1991, p.179). In contrast, others felt that the technology was simply a novel, transitory instructional medium and not the cause of any instructional impact . "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" (Clark, 1983, p.445). Comparative studies have been faulted for their narrow focus on measurement of the media effect as an absolute factor, exhibiting a "tendancy to treat each medium as more of less invariant with fixed clusters of attributes... [when] it is not the medium but rather the attributes that make a difference in learning" (Williams & Brown, 1991, p.45). In order to best exploit the potential of CAI, research needs to examine different attributes of the technology and identify which are useful in given contexts (Roblyer, 1985). Too often, it is forgotten that CAI itself "is not inferior or superior, but rather more or less well suited to the learner or to the message"

(Hagler & Knowlton, 1987, p.84) in the context in which it is employed. The contextual significance of CAI effectivness is only now being reflected in the research:

> Current CAI research interest is turning away from earlier media comparative studies due partially to the difficulty controlling the number of significant variables in learning, and also to the fact that CAI has proven to be relatively effective. New trends in CAI research are to try to investigate which computer features make it a preferred instructional medium over other media without these features; moreover under which specific conditions computers will be the most adequate instructional medium (Colorado, 1988, p.231)

This concern with identification of features which are indicative of effective CAI is an essential stage in the maturation of the field of technological research (Bork, 1990). It is only by identification of characteristics of effective programs that the true value of CAI can be assessed and, consequently, this area warrants further attention.

Section 3: Characteristics of Effective CAI

Assessing the value of computers in instruction is at best a difficult and confusing task. The quality of courseware developed for CAI can be assumed neither to be consistent across all programs nor to be effective in all situations where it is currently employed. Much of the software produced during the earlier stages of CAI was not considered instructionally effective nor indicative of the full potential of computers in instruction (Blum Cohen, 1983). More recently, the EDUCOM/NCRIPTAL Higher Education Software Awards program (Bangert-Drowns & Kozma, 1989) cited that only 5-7% of instructional software had been judged to be highly effective and worthy of recommendation. Explanations for this lack of quality have concentrated on the lack of design standards for courseware development and the absence of concern with the effectiveness of the programs which are produced (Merrill, 1987; Schaefermeyer, 1990; Vargas, 1986).

The lack of consistent quality in the software has resulted in massive confusion as to the overall effectiveness of CAI which in turn results in both an underestimation of the computer's power in instruction as documented in the research and the underuse of the resource as instructors fail to see any benefit from inclusion of CAI in their classrooms. In 1982, Forman identified a crisis in the quality of the software available:

> The problem of ensuring an adequate supply of quality courseware and of training teachers how to use the computer in an effective manner will continue to impede the widespread integration of computer technology into the school system (Forman, 1982, p. 49).

Nearly a decade later, the situtation had not significantly improved when Kettinger (1991) identified a "blatant deficiency" in the quality and range of courseware developed, citing the absence of "interesting, well-structured, clear and easily interactive software" (Kettinger, 1991, p. 39) as a major impediment to integration of computers in the classroom. Similarly, Duin (1988) identified the necessity of good design in development of effective CAI:

> Whether CAI obstructs or promotes learning is determined by the ways in which it is designed and used. CAI can become a catalyst for revitalizing the way which students approach the process of learning, or it can simply be a new form of paper online. Researchers and instructors need to grasp the power of design and develop instructional displays which are powerful conceptual, linguistic, and visual tools for learning (Duin, 1988, p.54).

Additional knowledge as to the specific characteristics which are indicative of high quality software is "imperative to make the investments [in computer technology] productive "(Bangert-Drowns & Kozma, 1985, p.241) and "for computer based education to achieve full potential" (Merrill, 1987, p. 18). In the absence of such knowledge, "courseware of poor quality minimizes the superiority of CAI over traditional methods" (Sawyer, 1985, p.17). Without an understanding of how to develop high quality software, the vast amounts of time and money in place in educational computing are wasted; with such knowledge, the return on this investment can be maximized and CAI can be truly effective.

One of the difficulties in development of high quality software is sifting through the diverse opinions on exactly what criteria should be used to define the standards. Schaefermeyer (1990) lists 16 criteria for high quality CAI, ranging from a detailed planning prodecure to adequate support for implementation, with extensive attention to incorporation of specific design features. Others have proposed standards that can be amalgamated into three general approaches to CAI development: (a) an approach which focussed on the learner-medium interaction, with emphasis on response, feedback and stimulus control (Vargus, 1986); (b) a management-focused approach, with content, operational and instructional criteria being emphasized (Bangert-Drowns & Kozma, 1989); and (c) a display-focused approach, with greatest concern on screen design, graphic capabilities and message clarity (Sawyer, 1985). Common features to all these approaches include attention to support factors (planning, implementation, documentation), organization of content (clarity, pacing), and capitalization on specific design features (graphics, feedback, learner control). This last area, capitalization on design features, allows for maximum benefit to be obtained from the unique capabilities of the computer as a delivery system and is the area where the potential of computers is most severly underexploited (Kettinger, 1991; Merrill, 1987).

An understanding of the design attributes and their influence on the effectiveness of CAI is imperative for basic quality standards to be developed. This issue is ever increasing in significance and complexity as new computers and new programs are produced with greater power and flexibility to manipulate these attributes. In the early stages of microcomputer incorporation in instruction, Blum Cohen (1983) indentified features of CAI which were linked to higher achievement, including the mode of interaction, feedback, and learner control. Further research has identified a miriade of such design factors which are reflected in effective CAI (Table 1):

Table 1 Examination of research on design attributes

Design Feature	Research
Question placement and highlights	Schloss, Schloss, & Cartwright, 1985
Color, graphics, and animation, visual cues	Baek & Layne, 1988; Beck, 1991; Rieber, 1991 ; Steinberg, 1991
Mneumonic support	Morrison & Levin, 1987
Questioning and feedback	Merrill, 1987; Mory 1992; Surber & Leeder, 1988; Schloss et al, 1988
Expository text	Gillingham, 1988
Feedback delay, presentation order, display, error handling	Sawyer, 1985
Branching	Schaefermeyer, 1990

The range of research into design attributes of the computer presents a second issue in developing standards of high quality software: attention to the context of the studies. The research which has been done has been plagued by a focus on prescriptive theory rather than practical experience:

> Much of the literature on software development and design is nothing more than a report on what should be included based on someone's theory of instruction. These are research-based theories, but no one has conducted empirical research as to the effectiveness of the software when these theories are incorporated" (Schaefermeyer, 1990, p. 14).

The approach ignores the significance of the practical application, where " instructional concerns include only isolated features, such as 'feedback' or 'user control' without considering that these features may or may not facilitiate learning, depending on their context" (Bangert-Drownws & Kozma, 1989).

An example of the relevance of context when examining a design attribute can be seen when the feature of graphics is examined. A miriad of research has been done on this variable. and each study must be considered in its own context and not grouped as a general use (versus non-use) of the feature. While the role that graphics play has been identified as significant in determining whether CAI is effective, different studies have come to varied conclusions as to how that effect is best characterized. The role which the graphics play has been shown to influence the significance of this feature in determination of CAI effectiveness. Graphics used with text as mneumonic support were shown to be benefical over text support alone or no support (Morrison & Levin, 1987), but graphics used as feedback were shown to have no effect on learning (Surber & Leeder, 1988). The type of graphics used also has influence on the effectiveness of this variable. Animated graphics were more beneficial than static illustration and colored graphics have been shown to be more effective than black and white (Baek & Layne, 1988). In addition, the conditions under which these studies were done were far from equivalent. The effect of graphics in a fourth grade spelling course (Surber & Leeder, 1988), an eighth grade science class (Morrison & Levin, 1987) and a college-level writing course (Duin, 1988) could not necessarily be considered equivalent and generalizable between the studies. Not only the type of attribute, but also how that feature is incorporated in the program, has been shown to be relevant. To this end, the research on each design attribute must be assessed for use in particular contexts before the effectiveness of the feature can be generalized and quality standards can be developed.

Section 4: Learner Control

One of the design attributes of CAI which has attracted considerable attention is that of learner control. This is a general term, referring to a broad range of features dealing with student-directed manipulation of instructional events, their sequencing, and their pacing. It provides an option for the learner "to make decisions, to exercise control and to assume some amount or even total responsibility regarding their instruction" (Santiago, & Okey 1992, p.47). While not without its drawbacks, the idea of learner control is an inherently attractive concept where students are considered to be the best judges of their own understanding and are permitted to direct their own learning according to their own needs

> Learner control is "intuitively appealing [since it]....can alleviate boredom, frustration and anxiety because it enables students to skip over materials they have previously learned or avoid materials which they are not prepared to study. Learner control will maintain attention longer, involve students more deeply and perhaps give students greater insights (Steinberg, 1989, p. 117).

By capitalizing on the computer's unique ability to individualize instruction to the needs of each student, learner control has the potential to provide unique instruction for each student, avoiding boredom in high achievers and frustration in low achievers (Carrier, Davidson, & Williams, 1985; Steinberg 1989).

Learner control is not an absolute variable, where a program is designed either with the presence or absence of the feature; rather, it is "a relative concept" (Duchastel, 1986, p. 379), "a collection of strategies that work in different ways, depending on what is controlled by whom" (Ross, Morrison, & O'Dell, 1988, p. 140). Millheim & Martin (1991) envisioned this feature along a continuum with complete learner control at one end and complete program control at the other. The range within this continuum reflects the varying degrees of learner control which may be incorporated into CAI. Today, the possibilities for inclusion of learner control have been expanded beyond this simple two dimensional model, as such features as optional learner override of program control or combinations of program and learner control can be included as options.

The range of situations and manners in which learner control has been employed has lead to considerable confusion in the research. In order to sort out this confusion, it must be remembered that the studies which have been done do not identify if learner control was beneficial or not, but if the degree of learner control was appropriate in the given circumstance. In addition, the research has been been described as "somewhat conflicting" and "inconsistent across all research" (Milheim & Martin, 1991, p.99) as generalizations as to the nature and benefit of learner control are difficult to determine outside the specific setting of the studies. Because of the contextual relevance in the studies, Duchastel (1986) felt any single definition of learner control was overly restrictive:

> Since learner control is a concept which is defined only in relative terms, it is indeed through examples of its application that it can best be grasped (Duchastel, 1986, p. 383).

To this end, the range of mechanisms by which learner control has been introduced into CAI is of interest. Most learner control can be divided into three categories (control over pacing, sequencing and content), each of which is quite complex in and of itself. For example, pacing of the lesson can range from simple control over screen advance, permitting the learner to control the overall rate of the lesson as well as the amount of time each piece of information remains on the screen, to more indirect control over presentation using such features as text density on the screen (Ross et al, 1988). Sequencing can be controlled in a variety of manners including branching from a single menu with multiple options or several smaller menus (Gray, 1988), or by a hypertext-based organization. Content control includes control over such features as review material (Gray 1989), feedback to error responses (Schloss et al, 1988), instructional options (Carrier et al, 1985), and context for examples (Ross, Morrison, & O'Dell, 1989). The degree of learner control employed has also varied between studies. Generalizations between and within these diverse categories has, consequently, been difficult. Positive, negative and neutral effects of learner control have all been cited (Milheim & Martin, 1991) in the far from consistent research.

The positive effects of learner control have been ascribed to the potential for individualization (Rowland & Steussy, 1988; Santiago & Okey, 1987), where the computer "systematically provides for different needs and abilities" (Carrier et al, 1985) of the learners within a single program. Program control, in contrast, has been considered "unnecesarily restrictive" (Laurillard, 1987, p. 3). Provision of control of the instruction to the learner allows the learner to play an active role in the learning process (Hannafin & Colamaio, 1987) and to determine his/her own needs and to judge how he/she learns best. This approach to instruction, referred to as a "communication model of learning" by Laurillard (1987), permits the student to experience the content in a personally relevant manner and construct his/her own perceptions free from prescribed program constraints. "There is no well-established reason to suppose that a program designer, whether teacher, researcher, or programmer, knows better than the students how they should learn" (Lauillard, 1987, p. 5).

In contrast to Laurillard's model, much of the research has argued that, in many cases, the learner is unable to direct his/her own learning effectively.

> It seems unreasonable to assume that young students would possess sufficient metacognive skills, subject matter knowledge, and self-discipline to be able to diagnose personal needs and follow through accordingly in their selections of practice materials (Morrison, Ross, & Baldwin, 1992, p. 12).

This view was supported by Carrier et al (1985), Hannafin (1984), and Steinberg (1989), who defined criteria under which learner control was or was not appropriate. Learner control has been shown to be most effective when dealing with high order skills, familiar material and drill/practice material while program control has been shown to be best for procedural tasks, verbatim learning, and unfamiliar material (Hannafin, 1984). The increased need for support material such as guidance, highlighting or objectives, for areas with which the learner is unfamiliar (Carrier et al, 1985) was required as learners lacked the ability to discriminate critical from tangential information and lacked subject-specific learning strategies (Steinberg, 1989). Even in these circumstances, as familiarity with the subject increased, learner control could be gradually phased into the program without deterimental effect (Steinberg, 1991).

Specific characteristics of the learners also were shown to influence the effectiveness of learner control. The effects of learner control over a given variable could not be assumed to be constant in settings where the learners differed greatly with respect to level of education, age or gender. For example, learner control over the context for examples and problems was examined in both a sixth grade math class (Morrison et al, 1992) and in an undergraduate education course (Ross et al, 1989). In both studies, learner control had no effect on academic achievement; however, learners' choice of contexts varied considerably more at the college level and achievement was seen to be positively related to the frequency with which the subjects varied the types of examples across lessons. The gender of students has also been shown to be related to the effect of learner control. In the Kinzie et al (1992) study of learner control over content reviews, learner control was found to improve motivation in males, but had no effect in females. Without an understanding of the significance of these learner characteristics, the effectiveness of learner control has the potential to be confounded.

The manner in which the effectiveness of learner control is measured has also caused conflicting results in the research. The use of academic achievement as a determinant of the success of learner control has provided the most varied results. Learner control has been shown to have negative influence on academic achievement when the students are permitted control over substantive content, such as instructional options (Carrier et al, 1985), review materals (Gray, 1987, 1988) and instructional support conditions (Morrison et al, 1992). Mixed or neutral effects were seen for posttest measures in other studies (Gray, 1988; Kinzie et al, 1992; Murphy & Davidson, 1991; Ross et al, 1988, 1989; Schloss et al, 1988) but several of these studies showed positive effects when academic benefit was assessed using other measures such as time efficiency (Murphy & Davidson, 1991; Schloss et al, 1988) long term retention (Gray, 1988; Murphy & Davidson, 1991) and indirect benefit from varied contexts for practice examples (Ross et al, 1989). Slight positive academic effects were seen for learner control over text density (Ross et al, 1988), review (Gray, 1989; Kinzie et al, 1992) and content from descriptive menus (Gray, 1988).

Affective response to learner control, however, has been identified as the area which shows the greatest potential for benefit from this attribute. This is not to say that the affective response would be isolated from academic impact; rather, any positive attitudes toward learner control may in turn increase motivation and result in greater academic success in the long term:

> Personal control is linked closely with elements of personal causation and competence. Continuing motivation could be expected to produce greater long-range achievement through more frequent self-initiated contact with the subject field even though it does not yield an immediate achievement in a short-term study (Kinzie & Sullivan, 1989, p. 12).

Detectable positive effects were seen in a range of studies (Gray, 1989; Hicken, Sullivan, & Klein, 1992; Hintze, Mohr, & Wenzel, 1988; Kinzie et al, 1992; Kinzie & Sullivan, 1989; Ross et al, 1989, 1992) where higher levels of student control were associated with promotion of feelings of competence and heightened personal meaning, which correspondingly were reflected in increased intrinsic motivation in the learners (Kinzie et al, 1992). However, neither academic nor affective benefits can be understood without consideration of the contexts of the studies from which these generalizations were developed. The age level of the subjects, the type of content, and the specific nature of the options allowed (Carrier et al, 1985), as well as specific learner characteristics such as knowledge base (Murphy & Davidson, 1991) and locus of control (Lopez & Harper, 1989; Gray, 1989) all influenced whether learner control had a positive or negative impact on the motivation and attitudes of the subjects.

Other measures of learner control effectiveness have provided equally interesting results and have shown that the complexity of learner control cannot be understood based on the simple presence or absence of this variable. Hicken et al (1992) examined different types of programs where the learner was given control either to add sections to a base of instruction (Leanplus) or to refrain from viewing optional sections (FullMinus). Students had a more positive attitude to the FullMinus approach and viewed more sections. Students viewing a LeanPlus lesson tended to exercise learner control more often than those on FullMinus and also spent more time on common instructional segments. The incentives given in this study also influenced how the learners viewed the lessons. Performance-contingent credit produced higher academic achievement than a simple task-contingent approach, with no corresponding attitude or time differences detected. These findings emphasized the importance of considering factors external to the learner control, such as procedural cues and incentive use, when examining the research to ensure the design of learner control is understood in context.

Before learner control can truly be understood, additional research must be done to examine the use of this attribute in a variety of contexts using the diverse measures which exist. Trends toward more student-centered and student-controlled programs, emphasis on interactivity of computers, and increased integration of computers in the schools all heighten the importance of understanding when, how and for whom learner control is best implemented (Swan & Mitrani, 1993). The increased need for additional research has been well-documented (Carrier et al, 1985; Hicken et al, 1992; Murphy & Davidson, 1991), especially in the expanding field of intelligent computer-assisted instruction (ICAI) where the potential for learner control of instruction through unplanned interactions and increased individualization of programs exists (Duchastel, 1986). Rather than having definitive answers as to the best way to handle learner control, the research has opened vast areas where the mechanisms through which learner control may be incorporated into a lesson and the kinds of benefits which can be obtained from this attribute are only beginning to be understood.

> The question of how to effectively offer learner control, already debated, may take on new dimensions as computer-based media provide greater instructional flexibility. There is an important and delicate balance between the goals of individual responsiblility and instructional efficiency which designers and researchers should continue to explore (Hicken et al, 1992, p. 25).

Summary

Computers have revolutionized education to a point where they are now present in nearly all schools, colleges, and universities in North America. However, their presence in the schools does not guarantee their use nor is their use in different situations equivalent. The number of students per computer, the number of faculty within each institution who use CAI, and the type(s) of use made of the technology all vary between institutions and in general indicate an underuse of the technology. However, a trend toward increased use of CAI has been identified as threshold levels of exposure to the technology are being been reached in more and more disciplines.

Considerable research has been generated dealing with identification of the characteristics of effective CAI, where the benefits and weaknesses of various design attributes have been examined. One such variable, learner control, has been studied using a range of criteria in a variety of settings. Any consensus as to the effectiveness of learner control has been qualified by the contextual relevance of the studies, where factors including sophistication of the learners, degree of learner control and nature of the control have all had a strong influence on the outcome of the studies. The complex research on this variable has opened vast areas for future study and a need for additional research dealing with this variable has been identified.

Chapter III

Methodology

General design of the study

This study followed a modification of the approach of McGrath (1992) where a pre-test/post-test/control group design was used to examine the significance of a design variable in the development of effective computer-assisted instruction. The effectiveness of learner control in relation to the learner characteristic of academic standing was measured using a set of tests spanning exposure to CAI. The independent variables were the level of learner control over review of background material for the lesson and the academic standing of the subjects; the dependent variable was academic achievement as measured on the pre- and post-tests.

The CAI lesson was developed relating to two units of the laboratory component of an introductory undergraduate genetics course, Genetics 197, at the University of Alberta. Each unit was developed in two formats:

1. Format 1 had a low level of learner control where review of background theory (previously presented in the laboratory and lecture components of the course) was mandatory before the students were permitted to proceed with the problem solving framework covered in the lesson.

2. Format 2 employed a high level of learner control where the learners could choose which, if any, review sections they wished to view using a LeanPlus menu option (Hicken et al, 1992).

A combination of these formats was used for the two units, either with format 1 for unit 1 and format 2 for unit 2 (referred to as Treatment Group A) or format 2 for unit 1 and format 1 for unit 2 (referred to as Treatment Group B). Pre- and post-tests were administered before and after the CAI for Treatment Groups A and B, while the control group (Treatment Group C) wrote the tests without viewing the CAI.

Table 2 Experimental treatments of each treatment group

Treatment Group	Unit 1 Treatment	Unit 2 Treatment
A	HIGH learner control	LOW learner control
B	LOW learner control	HIGH learner control
C (control)	no CAI	no CAI

Subjects

The sample for this study was composed of 102 volunteers from the students enrolled in Genetics 197, an introductory genetics course offered at the University of Alberta, in the Winter Term of the 1993/1994 academic year. Volunteers were excused from and given equivalent credit for a single laboratory report in exchange for their participation in this study; however, a substantial portion of the students chose both to participate in the study and to complete the report.

The volunteer group was deemed to be equivalent to the larger course population in terms of the students' programs of enrollment and academic standing (see appendix 1). The vast majority of the sample (76.6%) were Science students with representatives from five other faculties. Within the Science faculty, 71% were registered in General Science, 14.5% were Specialization students and 14.5% were Honors students, which closely approximated the makeup of the larger population. The sample also represented students from all levels of achievement, with 15.5% classified as low, 61.1% as mid-level, and 23.3% as high, where the students' standing on the mid-term examination was used as the criterion. The sample was not strongly biased with respect to the proportion of individuals of either gender, as both the sample and the course population had more females than males; however, the sample favored females to a slightly greater degree (3:2 females to males).

Of the one hundred two (102) students who volunteered for the study, three withdrew at the onset of the study, three were used in a pilot test of the materials, and six withdrew during the course of the study. The data related to these individuals were not included in the statistical analysis, leaving a total of 90 students employed as the sample.

The subjects for this study were randomly assigned to three treatment groups, where Groups A and B received CAI in addition to the traditional instruction and Group C received only traditional instruction. The variance in the numbers in the groups reflects the uneven dropout of volunteers after assignment of the subjects to the treatment groups (Apppendix 1).

Materials

A. Instructional materials

Hardware and courseware

The CAI program used in this study dealt with Mendelian analysis of both monohybrid and dihybrid crosses, corresponding to Exercise 3 and 4 in the Genetics 197

Heredity Laboratory Manual. The 1.6MB program covering both topics was developed using the authoring system, Authorware Professional, on a Macintosh IIci computer and was run in the Macintosh lab, Faculty of Education, University of Alberta, on a network which employed Macintosh LCIIs. Lab facilities allowed for 20 students to view the program independently at any one time. The facilities were utilized over a period of 1.5 weeks during which time the number of students varied from five to twenty individuals present in the lab at one time. Overlapping start times were used to accommodate the schedules of the volunteers.

Design of the CAI program

The purpose of the CAI program used in this study was to provide students with a framework for problem solving in Mendelian genetics. Students received information in both lectures and laboratories as to the theoretical concepts of gene transmission during meiosis and fertilization, the two concepts on which Mendelian genetics is based. Analysis of monohybrid and dihybrid crosses involved examination of the consequences of crosses between individuals and use of that knowledge of Mendelian genetics to identify both the cause of any effects seen and to predict the results of further crosses. The Genetics 197 course was organized such that students learned the basics of Mendelian genetics in the lecture, saw the theoretical principles in operation in actual settings in the laboratory and then used that information from both lectures and labs to carry out problem analysis. The ability of students to apply the information from traditional instruction to problem analysis was identified by the Genetics department as the area which most urgently required additional instruction and was, therefore, the topic chosen for the CAI developed for this study.

The structure of the CAI program capitalized on the thoery presented in the traditional instruction, providing a review of the background information on Mendelian genetics presented in lectures and labs incorporated into the framework for analysis. The review material was either under program control (mandatory review of all material) or learner control (with the ability to chose which sections would be viewed by adding these options to the base lesson). Each unit was presented with four sections: a review of entry-level background (either compulsory or optional) incorporated into a sample analysis, followed by three sample problems which the students were required to complete. Each sample problem followed the same basic framework for analysis (see Appendix 2 for an outline of the framework used). The sample problems increased in difficulty and decreased in the amount of support and direction which was provided as the student progressed through the section.

While the framework for analysis followed the same basic stages in monohybrid (unit 1) and dihybrid (unit 2) analysis, these two units were distinct with separate concepts and unique comprehension required for problem solving of each. An understanding of the framework for monohybrid analysis (unit 1) was insufficient for comprehension of the framework for unit 2, and vice versa. The pre- and post-tests concentrated on the areas of analysis which were distinct for the two topics, measuring the understanding of those areas which were unique to each unit.

To ensure the program both covered the two topics in a comprehensive manner and that the units were not subject to confounding due to the common material in the framework, a prototype was developed and subsequently test during the third week of February, 1994. Two laboratory coordinators for Genetics 197 who were responsible for the design and development of the lab component of the course, along with three volunteers from the sample and two laboratory instructors (graduate students in the Department of Genetics), participated in the examination of the prototype. Reaction to the content and design of the program was positive from all participants. The validity of the materials and the distinction between the concepts tested in unit 1 and unit 2 were verified by the content experts. Only minor cosmetic changes were suggested to ensure consistency between the lecture, lab and CAI materials. These changes were incorporated into the program before its use in the full study.

Handouts and explanatory information

Initial contact with the students involved only a brief oral description of the study, and a full description of the study was provided orally during scheduling of the computer facilities and in print upon student arrival at the computer laboratory facilities. The use of the computer, the use of the courseware, and the accessibility of the computers were discussed along with information tying the CAI into the traditional lecture and laboratory materials. Handouts were provided detailing the nature of the study, the assignment of students to the treatment groups, and directions on how to access the CAI program (Appendix 3). Additional directions were incorporated into the CAI lesson to guide the students through the program.

B. Evaluation instruments

The pre- and post-tests were designed to evaluate the students' ability to transfer the applied concepts and the framework for problem solving, dealt with in the program, to different contexts. These contexts varied as to the types of organisms used, the relationships between the variables in the problems, the nature of results generated, and the predictive/explanatory nature of the questions. The first drafts of the pre- and post-tests had two complex questions on each unit, where the students were asked to use phenotypic information to identify genotypic causes and predict outcomes in previously unknown contexts. Each of these complex questions had multiple subsections which required extensive independent analysis. The questions were taken from an accumulated test bank used by laboratory and lecture instructors for Genetics 197. Each question on the pre-test was matched with a second question from that same subsection of the test bank, matched for general topic and difficulty. One question was replaced on the first draft of each of the pre- and post-tests at the request of the lab coordinators in order to match more closely the difficulty level of the laboratory assignment for which volunteers were given credit in exchange for their participation (Appendix 4). The content experts confirmed that the pen and paper instruments replicated, with a high degree of fidelity, the content of the CAI lesson and that the pre-test was an equivalent testing instrument to the post-test in terms of both content and difficulty.

Procedure

During the week of January 17, 1994, students enrolled in Genetics 197 laboratories were advised by the laboratory coordinators of a study involving the use of CAI in genetics. At that time, volunteers were guaranteed equivalent credit for an exercise due the first week of March, 1994, in return for their participation in the study. General information about the study was provided, but no details of the purpose of the study or more precise directions were provided. One hundred and two (102) students indicated an interest in the study and were contacted by telephone by the experimenter during the week of February 7, 1994, when full disclosure of the nature of the study was provided and a schedule was established. At this time, three students withdrew at the onset of the study. Three volunteers were chosen to participate in a pilot test during the week of February 14, 1994. During this week, two graduate student lab instructors and the two lab coordinators also viewed the prototype of the CAI. Each individual participating in the pilot study viewed the CAI and the evaluation instruments individually, in order that observations as to his/her progress through the lesson and potential areas of difficulty could be identified and discussed. Suggested changes to the

CAI, including minor terminology modifications and inclusion of more detailed instructions on the use of the computer, were completed and two questions on the tests were changed to those provided by the lab coordinators. The modified lesson and evaluation instruments were used for the full study during the first two weeks of March, 1994.

Upon arrival at the computer lab, students were provided with a handout outlining the study and given instructions on the use of CAI (Appendix 3). Full disclosure was again provided and the experimenter was present to answer any procedural or content questions which arose. From the pilot test, expected times for completion of the study were 30 minutes for each of the tests and 90 minutes for each of the units, totalling four hours for the full study. Accordingly, students in Treatment Groups A and B were scheduled for two 2-hour sessions with considerable flexibility if extra time was required. Seven students in Groups A and B were unable to schedule a second day and were permitted to complete the full study in a single sitting. Those students completing the lesson on two separate days did so with a three working-day separation between sessions. Students in the control group were scheduled for two 30 minute sessions which were also three working days apart, after which time their commitment for this study was completed and they were given the option of viewing the CAI at their leisure. All students in the control group chose to exercise this option and complete the CAI lesson. Four control group students completed both the pre- and post-tests on a single day due to scheduling difficulties. The actual times for completion of the pre-test ranged from 15 to 50 minutes, the CAI lesson for both units from two and one half to seven hours, and the post-test from 20 to 40 minutes. In general, less time was required to complete the CAI in the high learner control format than in the program control format, as learners viewed fewer review sections when presented with the option of choosing which sections they wished to view. Upon completion of the study, any concerns were addressed and an answer key provided for those students who wished to see the responses to the pre- and post-test questions.

Chapter IV

Presentation of Results

Introduction

The findings of this study are detailed in this chapter, with an analytical focus on answering the research questions set forth in Chapter 1. Initially, presentation of the differences between the CAI treatment groups and the control group are detailed. The effect of learner control is then examined more closely as the results for the two CAI-receiving treatment groups are analyzed. Finally, the interaction between academic standing of the learner and learner control effect is examined.

Learner Control Effect: Between-Group Analysis

The structure of this study assigned students to three treatment group where Treatment Group A and B received CAI in addition to the traditional instruction and Treatment Group C acted as a control, receiving only traditional instruction. The CAI was designed to cover two units of Mendelian genetics, where a high level of learner control was employed in one unit and low learner control was employed in the other u for the CAI-receiving groups. These two groups differed in the order in which the learne control was assigned, with Treatment Group A having high learner control for unit 1 and low learner control for unit 2 while Treatment Group B received the reverse. For each unit, one test was administered at the start of the study (a pre-test) to establish a baseline achievement value and one was administered after treatment (a post-test) to measure any alteration in students' understanding of the concepts presented in the lesson after exposure to the CAI. The raw data (presented in Appendix 5) were used to calculate descriptive statistics and the results are summarized in Table 3, showing increases from pre- (x_1) to post- (x_2) test mean scores for all treatment groups in both units.

Table 3 Mean Achievement Scores for Pre- and Post-tests

Treatment Group	Number of Students	Unit 1 Score	Unit 2 Score
A	31	$x_1 = 30.32 \pm 14.55$ $x_2 = 60.16 \pm 22.12$	$x_1 = 59.17 \pm 31.35$ $x_2 = 68.83 \pm 25.14$
B	36	$x_1 = 36.39 \pm 16.06$ $x_2 = 67.92 \pm 17.58$	$x_1 = 69.46 \pm 25.14$ $x_2 = 77.70 \pm 20.02$
C [Control]	23	$x_1 = 35.22 \pm 20.92$ $x_2 = 66.74 \pm 20.92$	$x_1 = 46.09 \pm 27.22$ $x_2 = 60.22 \pm 19.80$

Analysis of the three treatment groups was done in both units in order to provide answers to the first two research questions. The general impact of the computer-assisted instruction was the focus of the first question:

> Is there any difference between the achievement of students receiving CAI in each of the two formats in addition to the traditional instruction and that of students receiving only traditional instruction?
>
> Comparison: Group A v. C and Group B v. C

The second research question examined the effect of the different levels of learner control viewed by the two CAI-receiving treatment groups:

> Is there any difference betwen the achievement of students receiving CAI designed with a low level of learner control and that of students receiving CAI with a high level of learner control?
>
> Comparison: Group A v. B

In the first stage of analysis, identification of any differences between the three treatment groups was carried out using the post-test scores as the dependent variable. Initial one-way analysis of variance (ANOVA) of the post scores detected significant differences existing between the three treatment groups only in unit 2 (Table 5; Sig of F = 0.012). In unit 1, differences between the three groups were not significant (Table 4; Sig of F = 0.261).

Table 4 Unit 1 One-Way Analysis of Variance of Between Treatment Group Differences Using Post-test Scores as the Dependent Variable

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	Sig of F
Between groups	2	1 101.344	550.672	1.364	0.261
Residual	87	35 123.378	403.717		
Total	89	36 224.722	407.019		

Table 5 Unit 2 One-way Analysis of Variance of Between Treatment Group Differences Using Post-test Scores as the Dependent Variable

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	Sig of F
Between groups	2	4 430.246	2 215.123	4.656	0.012
Residual	87	41 387.809	475.722		
Total	89	35 818.056	514.810		

Further analysis of the results in unit 2 was done to isolate and identify the nature of the differences detected in the ANOVA. Contrasts were run for the treatment groups (Group A v. B, Group A v. C, and Group B v. C) using post test scores as the dependent variable in four separate tests: Scheffe's, Tukey-HSD, Tukey-B, and Bonferroni. In each of these tests, only a single contrast was shown to be signficant in unit 2, that of Group B v. C (Table 6).

Table 6 Between-Group Contrast Test Results

Unit	Difference detected	Test	Sig. Level
1	no significant difference	Scheffe Tukey-B Tukey-HSD Bonferroni	0.05
2	Group B v. C (means: 77.70 v. 60.22)	Scheffe Tukey-B Tukey-HSD Bonferroni	0.05

However, initial differences between subjects as measured by the pre-test had the potential to confound the results. Consequently, analysis of the between group differences was repeated with the inclusion of the pre-test scores as a covariate for the dependent variable, where the effect of the covariate was seen to be significant (Tables 7 and 8). The results obtained from this round of analysis showed no significant differences attributable solely to between-treatment group differences (Sig of F = 0.416 for unit 1 and 0.134 for unit 2).

Table 7 Unit 1 Multiple Analysis of Variance of Post-test Scores using Pre-test Scores as a Covariate

Source	Sum of Squares	D.F.	Mean Squares	F	Sig of F
Within + Residual	33 475.39	86	389.25		
Covariate	1 647.99	1	1647.99	4.23	0.043
Treatment Group	689.59	2	344.80	0.89	0.416
Model	2 749.33	3	916.44	2.35	0.078
Total	36 224.72	89	407.02		

Table 8 Unit 2 Multiple Analysis of Variance of Post-test Scores using Pre-test Scores as a Covariate

Source	Sum of Squares	D.F.	Mean Squares	F	Sig of F
Within + Residual	36 541.80	86	424.90		
Covariate	4 846.01	1	4 846.01	11.40	0.001
Treatment Group	1 745.35	2	872.67	2.05	0.134
Model	9 276.26	3	3 092.09	7.28	[illegible]
Total	45 818.06	89	514.81		

Learner Control Effect and Academic Standing: Interaction Analysis

The third research question examining the relationship between academic achievement and the effect of learner control was studied:

> Does the academic standing of the learners (i.e. low v. mid v. high achievers) have any influence on the effect seen for different levels of learner control?

In the final phase of analysis, attempts were made to identify the interaction between a single learner characteristic, academic standing, and the effect of learner control. Academic standing of the learners was measured using a three-tiered scale (low/mid/high achievers) based on mid-term examination scores. Contrasts were run to identify which factors had a significant impact in two-way analysis of variance of learner control and academic standing effect using post-test scores with pre-test scores as the covariate (Tables 9 and 10). The significant differences were identified based on the varying academic standing of the learners in the first unit (P=0.005) and a significant interaction between the level of learner control and learner academic standing in unit 2 (F= 0.034).

Table 9 Contrasts of Factors Influencing Achievement in Two-Way Analysis of Learner Control Level and Academic Standing for Unit 1

Source	Sum of Squares	D.F.	Mean Squares	F	Sig of F
Covariate	984.68	1	984.68	2.94	0.092
Treatment Group	297.50	1	297.50	0.89	0.350
Academic Standing	3 839.82	2	1 919.91	5.73	0.005
Interaction [Group x Academic Standing]	123.56	2	61.78	0.18	0.832

Table 10 Contrasts of Factors Influencing Achievement in Two-Way Analysis of Learner Control Level and Academic Standing for Unit 2

Source	Sum of Squares	D.F.	Mean Squares	F	Sig of F
Covariate	1 775.74	1	1 775.74	4.39	0.041
Treatment Group	1968.31	1	1968.31	4.86	0.031
Academic Standing	678.82	2	339.41	0.84	0.438
Interaction [Group x Academic Standing]	2 900.26	2	1 450.13	3.58	0.034

Adjusted means for each academic standing subgroup were calculated (Table 12). The relationship between the two levels of learner control across learner categories can be best visualized when these adjusted means are presented graphically in Figures 1 and 2. A significant interaction is seen only in unit 2 where the relationship between high and low levels of learner control is not constant for all types of learners.

Table 12 Subgroup Adjusted Means

		Academic Standing		
Unit	**Treatment Group**	**Low**	**Middle**	**High**
1				
	A [high learner control]	31.57	54.34	61.72
	B [low learner control]	42.69	57.41	63.69
2				
	A [low learner control]	72.18	56.92	69.26
	B [high learner control]	35.95	60.53	62.13

Figure 1 Unit 1 Learner Control Interaction with Academic Standing

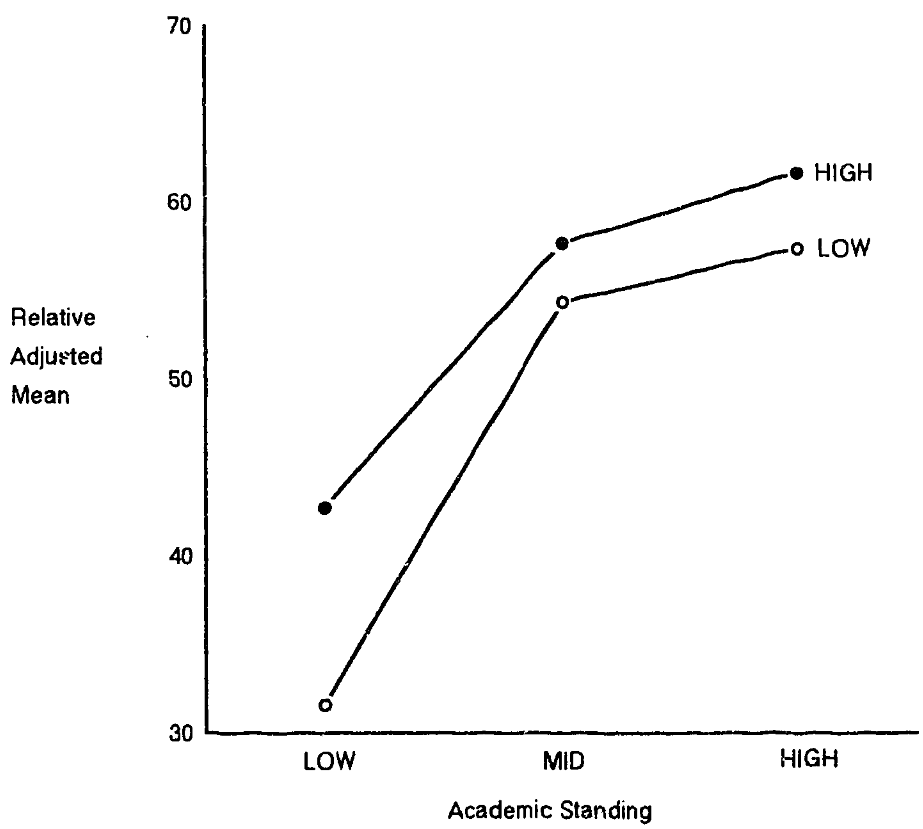
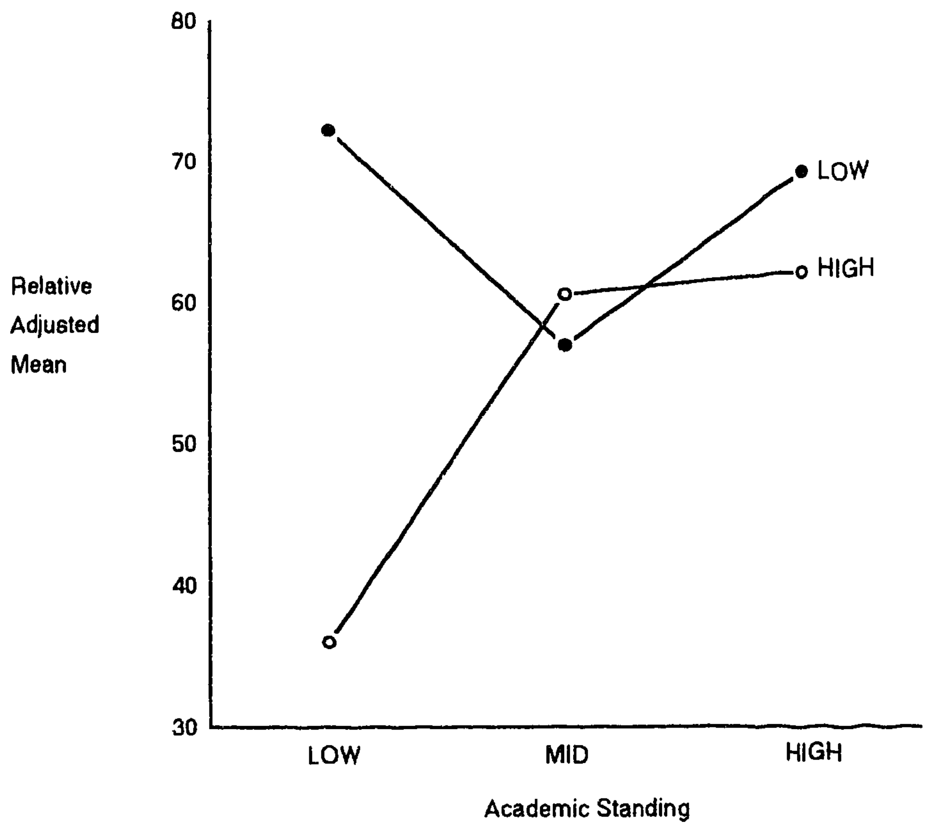


Figure 2 Unit 2 Learner Control Interaction with Academic Standing



A further test was run on the data to identify any significant differences between the levels of learner control at each of the levels of academic standing (Tables 13 and 14). Only a single significant difference was identified in the two units: the poor learners in unit 2 showed significantly greater gains associated with low learner control, in the comparison of high and low learner control levels for students of low academic standing (P=0.0095).

Table 13 Unit 1 Differences between Learner Control Levels for Each Class of Academic Standing

Academic Standing Category	D.F.	Sum of Squares	Mean Squares	F Ratio	Sig of F
Low	1	238.7158	238.7158	0.7129	0.4019
Mid-range	1	92.0361	92.0361	0.2748	0.6020
High	1	15.9555	15.9555	0.0476	0.8280

Table 14 Unit 2 Differences between Learner Control Levels for Each Class of Academic Standing

Academic Standing Category	D.F.	Sum of Squares	Mean Squares	F Ratio	Sig of F
Low	1	2 904.982	2 904.987	7.17	0.0095
Mid-range	1	126.133	126.133	0.312	0.5788
High	1	207.895	207.895	0.514	0.4764

Summary

This chapter presented the statistical examination of the achievement associated with the CAI-receiving groups and the control as measured by the pre- and post-test scores on two separate units (monohybird and dihybrid analysis). No significant differences were detected between the control group and the treatment groups in unit 1 (Sig of F = 0.261); however, in unit 2, signficant differences were detected between the group receiving a high level of learner control (Treatment Group B) and the control group (Treatment Group C) (Sig of F = 0.012). When the influence of initial differences as measured by the pre-test were removed, however, no signficant between-group differences were detected (Sig of F = 0.416 for unit 1 and 0.134 for unit 2). When the effect of learner control was examined in relation to the academic standing of the students viewing the CAI, an interaction was detected only in unit 2 (Sig of F = 0.034), where low learner control was much more effective than high learner control for poor learners while the effect of the two levels of learner control was not signficantly different for learners of other academic standing.

Chapter V

Discussion

Introduction

This section details the results of this study in the context of other research and provides a discussion of how this work can be interpreted. The impact of CAI employing different levels of learner control and the importance of contextual factors on this effect are the central themes in the interpretations of these findings in terms of effective CAI development. Finally, implications of this work in terms of projections for future research are identified.

Summary of Results

This study examined the effect of different levels of learner control in a computer-assisted instruction (CAI) program where pre- and post-test scores from a set of quizzes were used as the measure of the achievement effects of the treatments. Initial analysis identified significant differences existing between the three different treatment groups only in unit 2, the unit dealing with dihybrid cross analysis; no significant differences were detected in the first unit which covered monohybrid cross analysis. Further analysis of unit 2 revealed that the group receiving CAI with a high level of learner control was associated with significantly greater scores than the control group. However, once the effects of pre-test differences were removed as a covariate, no significant differences were detected between treatment groups. When academic standing of the learners was examined, the results differed between the topics/units to which the different levels of learner control were assigned. Only in unit 2 was a significant interaction detected between the academic standing of the learners and the level of learner control employed. In unit 1, achievement scores increased as the academic standing of the learners increased, and that relationship was consistent over for all categories of student academic standing. In unit two, the relationship was not constant; poorer students performed significantly better under low learner control levels while mid-range and higher achievers did equally as well under either level of learner control.

Interpretations and implications

Research in computer-assisted instruction has evolved from comparative studies involving the academic advantages of CAI use versus traditional instruction (Clark, 1985; Kulik et al, 1980) to more diagnostic studies where characterization of the specific features of CAI which provide the media with unique instructional capabilities is the focus (Bork, 1991; Ely, 1989; Mory, 1992). This study fits the latter category where examination of a single design feature, learner control, was carried out. When any design features is studied, a differentiation must be made between the examination of factors inherent to the feature itself and the investigation of environmental factors external to the feature. Previous studies have examined internal factors which define the learner control feature, such as the degree of learner control which is appropriate (Milheim & Martin, 1991; Ross et al, 1988), the lesson constituent over which learner control is provided (Gray, 1989), and the manner in which control is given to the learner (Gray, 1988,1989). While these factors provided primary information on the intrinsic effectiveness of learner control as a design feature, other studies have concentrated on consideration of external factors which impact this effectiveness. The Hicken et al study (1989) examining the importance of incentives given, the Goetzfired & Hannafin's research (1985) on learner characteristics, and the Ross et al work (1989) with different topic contexts are all examples of research which has provided contextual information on factors which influenced learner control effect. Identification of internal factors has assisted in the development of a knowledge base on the design feature; however, without identification of the external factors which show significant interaction with the learner control, there is no context for this knowledge base and the feature's potential could be underestimated or its impact overgeneralized as a result. The analysis in this study combines internal and external elements, focussing on the internal factor of the degree of learner control employed (either high or low levels) as well as the external factors of the academic characteristics of the learners involved in the study and, indirectly, the unit context in which learner control was implemented.

The initial phase of the analysis dealt with identification of the effectiveness of different learner control levels within the general context of the study. In both units, the use of CAI in one or both units was slightly beneficial to the control group, but only in the second unit were significant differences detected between a CAI-receiving group and the control group. In unit 2, students receiving a high level of learner control performed significantly better than the control group while those receiving a low level showed no such difference. In neither unit were significant differences detected between the two CAI-receiving groups. The differences detected in the initial stage of analysis will be the immediate focus of the discussion; the absence of differences will be examined in a later section where the effect of the covariate is detailed.

The nature of the control given to the learner is of paramount importance in determination of the effect seen. In much of the previous research involving learner control over review material (Gray, 1987. 1988; Kinzie et al, 1992; Kinzie & Sullivan, 1989), the review entailed a re-examination of key points presented in the CAI immediately upon completion of a section(s) of the lesson; in contrast, the review in this study involved an opportunity for students to re-examine information pre-requisite to the lesson whenever such background information was utilized in the CAI lesson. In the low level learner control version of the unit, review of the background material was mandatory; with high levels of learner control, the learner was given the option to review the background material at several points in the lesson where comprehension of such informaton was essential in order for the learner to proceed with the sample problem analysis. By structuring the optional review in a context coincident with an example, the deficiencies in the background became obvious to the learner *in situ*. In this manner, this study established an environment where the learner could exercise control over a feature over which he/she, rather than a programmer or instructor, could be considered to be the best judge of the need for review. The provision of control over such an area has previously been cited as a context where learner control is most appropriate (Laurillard, 1987). The results for this study support such a theory in part as high learner control was the only treatment showing significantly higher achievement scores, although only in one of the two units.

As signficant differences were detected between treatment groups in only one of the two units and, consequently, examination of the post-test scores also revealed information on the importance of unit context for the learner control effectiveness. The absence of equivalent effects across units can be attributed in part to the topics covered in each section. Unit 1 dealt with monohybrid crosses where the problem solving involved the visualization of cell division and the tracking of chromosomes through the processes of meiosis and fertilization; unit 2 was concerned with deductive and inductive reasoning based on the relationship between two genes in dihybrid crosses. The distinction in the results for the two topics may be due to different requirements for comprehension of background material in the two settings, different cognitive tasks involved in the units, or some other such factor which resulted in differing values for the review in context. This supports previous research which indicated that high learner control is more effective than low levels of learner control when dealing with higher order tasks (Hannafin). Higher levels of learner control were more appropriate and were associated with significant achievement in the more complex topic, unit 2. Complexity is not the only distinction betwen the topics, however; the role of other support measures varied between two units. Several such factors including graphics, animation, and visual cues have been identified (Baek & Layne, 1988; Beck, 1991) and it is possible that an interaction between these factors and the learner control influenced the effect seen here. Further investigation of learner control over various topics, over different portions of the lesson, and in conjunction with a wide range of variables is required in order to develop generalizations as to which aspects of the between-unit differences were responsible for determination of learner control effect.

In addition to the nature of the topics, another factor, the order of exposure to the different levels of learner control, was integral to the study and cannot be discounted as having an influence on learner control effect. Treatment Group A had a high level of learner control in unit 1 and low level in unit 2 while Treatment Group B had the reverse order, with a transition from low to high levels of learner control from unit 1 to 2. An argument could be made that familiarity with the structure of the lesson was necessary for the learners to possess sufficient sophistication to make effective use of the high learner control. Treatment Group A may have lacked that knowledge and sophistication at the outset of the study, a deficit all the more intensified since this study is the first exposure to CAI in this course. The students would not necessarily have had previous exposure to CAI. Consequently, a lack of familiarity with the review option may have biased the results if the learners in Treatment Group A were unable to exercise the high level of learner control effectively due to inexperience. Treatment Group B, in contrast, would have been intiated with the structure of the review in unit 1 where they were required to see all review sections (low learner control). By the time these students had reached the high level of learner control in unit 2, they may have had the familiarity requisite for effective use of the learner control. Their more sophisticated choices would be reflected as the signficantly higher scores and the structure of the study, rather than differences inherent to the units, would have been responsible for the results seen.

The possibility also exists that some notable variation between the sample assigned to each treatment group was responsible for the differences detected. While the treatment groups appeared to be similar with regard to the demographics examined (i.e. academic standing, gender and program of enrollment), certain biases were detected. The control group was heavily dominated by females at a ratio of three females for each male. As well, Treatment Group B contained a relatively greater proportion of high achievers than the other groups. Also, several other variables which may have influenced the results were not examined. For example, the treatment groups may not have been equivalent on the basis of year of program of enrollment or number of related course taken. Interaction between these external factors and learner control may have been context dependent and any potential bias could have influenced each group's reaction to the CAI and the tests.

The effects seen were not equivalent, however, once initial differences between the learners in the three treatment groups were removed through use of pre-test scores as a covariate. After the covariate was included in the analysis, no significant between-group differences were detected in either unit. Much of the variation seen in the initial analysis could be attributed to differences existing between the groups at the onset of the study; without these differences, learner control level had no impact on achievement and the advantage attributed to high learner control in the previous analysis was absent.

The absence of differences between treatment groups is possibily attributable to the general structure of this study. For example, the temporal structure of the research may have negated any potential differences between differences. The short duration of the study combined with the dilution of CAI effect within the traditional instruction of leacture and laboratory may have been insufficient to create any significant effect. Also, signficant increases were detected from the pre- to post-test scores in all treatment groups for both units, including the control groups. This Hawthorne effect diminished the relative achievement gains of the CAI-receiving groups and resulted in underestimation of the impact of the CAI. Without a clear measure of CAI effect relative to the control, any measurement of the effect of learner control within that CAI was compromised.

It is also possible that any learner control effect in the secondary analysis was confounded by overly broad categorization of high versus low learner control groups which failed to take into account the effect of external factors. By partitioning the learners according to such an external factor, a more comprehensive understanding of the variable is made possible. The remainder of this study concentrated on the relationship between a single external factor, learner academic standing, and learner control effectiveness. In unit 1, no significant interaction was detected between the level of learner control and the academic standing of the learners, although the scores differed significantly between learners of different academic standing for both levels of learner control. A direct relationship existed with higher achievement associated with learners of higher academic standing (eg. low achievers scored significantly less than high achievers). While the three-tiered scale for academic standing (low/mid/high achievers) was sufficient to produce significant differences between the different learners, it may not have been sufficiently sensitive to reveal any interaction with the learner control level. It is equally possible that the criteria used to assign the learners to these categories was inadequate to provide an accurate assessment of learner academic standing. Each learner's description of his/her rank on the mid-term examination may have been subject to inaccuracy, whether due to faulty memory and biased outlook by the students, or due to poor estimation of the learners' ability by the single examination. The absence of any interaction in the first unit may also be attributed to the nature of the learners used in this study. The theory behind the association between academic standing and learner control is based on the assumption that "many students, especially low achievers, lack the knowledge and motivation to make effective decisions" (Morrison et al, 1992, p.13) in contrast to more sophisticated high achievers. This study involved adult learners at an undergraduate university level, who supposedly have acquired a high level of ability to diagnose their own needs and to motivate themselves before attaining such a level of education. This maturity may have negated the deficiencies of the low achievers, resulting in a more uniform sample group for the study and, consequently, lessened the differences between low and high learner control effect in terms of the interaction with learner academic standing.

In unit 2, to the contrary, the impact of the learner control level was much more marked and a significant interaction was detected between the academic standing of the learners and the two levels of learner control employed. The achievement on the tests was not equivalent for both levels of learner control across different academic standing categories; a low learner control level was significantly more effective for poorer learners (low academic standing) while the effects were not signficantly different between the two levels of learner control for learners of other academic standings. These findings support the research (Carrier, 1985; Hannafin, 1984; Morrison et al, 1992) which outlines the relationship between learner control and academic standing such that learner control given over substantive material requires a cognitive base and sophistication for the learners to make effective choices. Poorer students will function better with less control in such circumstances where the instructor/programmer can be considered the better judge of what should be included in the lesson. This relationship was evident in the context of this study, learner control of background review, in much the same manner as was detected in previous research.

The difference between this unit and the one previous, where no such effect was seen, can be attributed in part to the nature of the topic studied. As mentioned previously, dihybrid cross analysis (the unit 2 topic) concentrates primarily on application of Mendelian principles to the relationship between genes and alleles; monhybrid cross analysis (the unit 1 topic) focusses on the visualization and tracking of chromosomes through a series of crosses. While these two topics are clearly related, the unit 2 topic is more difficult, involving more complex information processing and higher order thinking. In the first unit, the poorer students may either have possessed sufficient skills and knowledge to use the learner control effectively or any deficiencies in such skills may not have been as deterimental as in the later unit; however, in the more difficult environment, the difference in sophistication between high and low achievers would become more apparent, resulting in the differences detected only in this setting. These concerns were outside the scope of this research and, consequently, require additional investigation with a wider range of topics before any generalizations can be made.

A final possibility, the order in which the lessons were presented, may also have played a role in the differences seen between the two units. Unit 1 was the first exposure to CAI for the learners in this course; consequently, the high learner control level group may have viewed more, if not all, the optional sections due to unfamiliarity with the system. Their inexperience, a temporary influence, may have been manifested as a reluctance to miss any information in the lesson. In unit 2, the learners may have felt more confident in excluding certain sections as they became more familiar with the CAI. Only at such a time would differences in the judgement of the learners become apparent as the learners truly began to exercise the options presented with high levels of learner control. The poorer learners lack of sophistication would become more apparent under such circumstances. Similarily, previous exposure to the CAI in unit . may have engendered boredom or fatigue in the students, resulting in a failure to view any substantive amount of the optional sections in the second unit as the learners rushed through the lesson. The impact of this superficial review may have been more severe on the poorer students for whom a review of background material may be considered more essential. It is these students who lack both the knowledge of the material and the coping mechansims to proceed through the lesson without the review, and it is with these learners at this time that any differences based on differing academic standing would be detected.

While much of the results of this study have supported previous research findings, it is noteworthy that these results were not consistent across both units nor were they consistent across analyses when the effect of the covariate was considered. This further reinforces the importance of context when evaluating the results of such research on learner control. Used in this manner, contextual relevance can be considered to be the sum of all external fators, including subject matter and measurement system, which may influence the effect of learner control either independently or through interaction with other factors. Without consideration of this contextual relevance, the effectiveness of learner control can only be examined in a vacuum without practical value. It is by inclusion of the contextual information that learner control can best be examined and it is toward this end that further studies should be directed.

Future research

The generalizability of this research is restricted by the structure of the study. The setting for the study was an undergraduate genetics course where comprehension of concepts required an understanding of basic principles in a variety of fields (eg. general biology, zoology, botany, microbiology, physiology). Review of background could be considered a substantive element of instruction within this context, where students enter with a broad range of entry level knowledge from varied areas. In other settings, the review of background material may not be equally essential to instruction if the learners are more uniform or the instruction is less dependent upon previous knowledge. Learner control over background review in such a setting may prove to produce alternative results. Identification of the relevance of context for this variable in these terms therefore warrants further attention.

Similarily, the review in this study was heavily contextualized (i.e. the requirement for review was established within the context of a sample problem, giving considerable guidance for the learner to make a choice). As well, substantial description of the optional sections was provided to guide the learner in making choices. The impact of these supportive measures was outside the focus of this study and is consequently unknown in this context. Previous research has suggested that such guidance increases the effectiveness of learner control (Gray, 1988; Hannafin, 1984; Morrison et al, 1992). Additional research on the relative importance of different forms of support for learner control is necessary to determine the extent to which supportive context manipulation influences learner control effect.

A final area for further study is the use of alternative criteria to measure impact of learner control over review of background information. Short term achievement scores are only one measure for the success of a program; long term retention, motivation, attitude, cost efficiency and time efficiency have all been used as measures in previous studies dealing with other forms of learner control (Gray, 1988, 1989; Hicken et al, 1992; Kinzie & Sullivan, 1989; Ross et al, 1992). No single design feature is effective for all learners in all contexts; only by expanding the research to examine learner control using multiple criteria can the most suitable contexts for each type of learner control be identified and the feature be fully understood.

Summary

In this study, a high level of learner control was seen to be beneficial within specific contexts, although not in all the sittings in which it was employed. The absence of signficant differences in the first unit emphasizes the importance of context on learner control effect as did the interaction of learner control with academic standing. The effect of pre-test scores on the results illustrated the danger of using a single measure of learner control effect to generalize the value of the feature. Too often contextual relevance for both the incorporaton of learner control and the measurement of that feature's effectiveness is forgotten in the examination of specific design features. It is not the merits of learner control itself in isolation but the feature's use in an appropriate context which creates any achievement effects seen. Correspondingly, the need to identify external factors is essential to prevent the wholesale discounting of learner control's merit when the context, rather than the feature's inherent potential is responsible for the phenomenon. Comprehension of learner control is, therefore, dependent upon the amalgamation of theory on learner control's intrinsic benefit with practical knowledge of contextual suitability.

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Appendix I Demographic Information on the Sample and Population

This section summarizes the demographic information collected from the sample for this study. The program of enrollment, academic standing, and gender of the sample are outlined. Population values are taken for the Genetics 197 course enrollment for 1994.

Table 15 Sample and Population Program of Enrollment

Group	Faculty					
	Science General	Science Special	Science Honors	Arts	Agriculture	Other *
Sample						
Treatment Group A	21.1% [19]	3.3% [3]	4.4% [4]	2.2% [2]	3.3% [3]	1.1% [1]
Treatment Group B	18.9% [17]	4.4% [4]	6.7% [6]	4.4% [4]	2.2% [2]	3.3% [3]
Treatment Group C	14.4% [13]	3.3% [3]	0% [0]	1.1% [1]	2.2% [2]	3.3% [3]
Total Sample	54.4% [49]	11.1% [10]	11.1% [10]	7.8% [7]	7.8% [7]	7.8% [7]
Population	56%	8.5%	5.6%	8.6%	7.1%	14%

* Other Category: Sample: Education

Population: Education, Engineering, Physical Education, Commerce, Home Economics, Unclassified

Table 16 Sample and Population Academic Standing

Group	Academic Standing		
	Low **1 - 3**	**Mid-range** **4 - 6**	**High** **7 - 9**
Sample			
Treatment Group A	5.6% [5]	22.2% [20]	6.7% [6]
Treatment Group B	4.4% [4]	22.2% [20]	13.3% [12]
Treatment Group C	5.6% [5]	16.7% [15]	3.3% [3]
Total Sample	15.5% [14]	61.1% [55]	23.3% [21]
Population	16.7%	66.7%	16.7%

Table 17 Gender of the Sample and Population

Group	Gender		Total Number
	Male	Female	
Sample			
Treatment Group A	13.3% [12]	21.1% [19]	31 students
Treatment Group B	17.8% [16]	22.2% [20]	36 students
Treatment Group C	6.7% [6]	18.9% [17]	23 students
Total Sample	37.8% [34]	62.2% [56]	90 students
Population	44.8%	55.2%	

Appendix II Framework for Analysis

This appendix summarizes the analytical framework presented in the CAI lesson. Each of the major stages used in analysis of monohybrid and dihybrid crosses is presented with a brief description of student role in the sections.

Framework for Analysis of Monohybrid and Dihybrid Crosses

Stage 1 Identify relevant information

The student must sort through the information presented in a problem and identify only those factors which provide signficant information to be used in the problem analysis. For monohybrid crosses, these factors include the number of genes, the number of alleles and the crosses done; the relationship between genes and linkage status are the focus in dihybrid analysis.

Stage 2 Convert phenotypes to genotypes

This stage involves the examination of the underlying causes for any effects seen. Students must either convert phenotypes directly from information presented or deduce the genotypes from the phenotypic information.

Stage 3 Track alleles through crosses

This stage involves knowledge of the processes of meiosis and fertilization, as well as an understanding of gene linkage and crossing over in the unit on dihybrid analysis, as students follow the transmission of genes and alleles through a series of crosses.

Stage 4 Convert genotypes to phenotypes

This stage concentrates on using the genotypic information to explain certain phenomenon or to predict the outcome of specific crosses. Using the information obtained in the previous stages, the students must apply basic Mendelian genetic principles to explain their conclusions.

Appendix III Introductory Handout for Volunteers

This appendix presents the handout provided to ths students involved in this study, outlining the general nature of the study, their responsibilities and initial instructions.

GENERAL DESCRIPTION

This study compares two formats for computer-assisted instruction (CAI) which differ in the amount of control the student has over the descriptive material seen. One format is used for the section on monohybrid crosses and the other for dihybrid crosses.

The computer lesson will involve a brief review of the theory of monohybrid and dihybrid crosses, followed by the presentation of a framework for problem analysis in each area. You will also be given the opportunity to work through some practice questions where your input is required.

Your participation in this study is purely voluntary. You have the right to withdraw at any time. If you must opt out for any reason, please contact the coordinator for further instructions. A list of participants will be given to the Genetics Department to ensure each volunteer will receive equivalent credit for the lab report dealing with dihybrid crosses. Aside from this list, your participation in this study is completely confidential; your identity is not required for the quizzes or in any part of the lesson itself. If you have a concern about any aspect of this study, please contact the coordinator in your session.

INSTRUCTIONS

Both before and after viewing the computer lesson, you will be required to complete a 20 minute quiz. These quizzes also also have a section which askes for demographic information (used to assess wherther the volunteers for this study are representative of the students taking Genetics 197 and to identify the relative benefits of the lesson for different students). Please complete the first quiz before proceeding with the computer lesson.

You have been assigned to the group viewing FORMAT A/B/C. Each time
the lesson, please ensure you view only this format.

Once you have gained entry to the lesson, simply follow the instructio
screen. You will view a brief introduction to the lesson which
instructions on how to proceed through the lesson, respond to qu
optional material. If you have any problems, please ask for assistance.

Appendix IV Pre- and Post-Tests

This appendix includes the cover sheet to obtain demographic information, the pre-test, and the post-test used in this study.

DEMOGRAPHICS

Gender: M___ F___

Faculty: ______________________________

Program: General ___ Specialization ___ Honors ___ Other ___

Year of program: ________________________

Please estimate your standing on the midterm examination for Genetics 197:

1-3 ___

4-6 ___

7-9 ___

1. In Caribbean weevils, purple ears (P) are dominant over yellow ears (p). Suppose a truebreeding purple male is crossed with a truebreeding yellow female. The progeny of this cross areselfed (F1 x F1).

How would you explain the results if the ratio of purple : yellow in the F2 is 1:1?

What if the ratio is 3:1?

2. In man, the blood types A, B, AB and O are controlled by three alleles (I^A, I^B and i) of a single gene, where I^A and I^B are both dominant to i but are codominant with each other. A man and a woman have four children. One of them is adopted and another is from the woman's previous marriage. Given that the woman is of bloodtype AB, the present husband is type O and the four children are of types A, O, AB, and B:

which of the chidren is adopted?

which is from an earlier marriage of the mother?

Show your reasoning.

3. In *Drosophila*, gray body color is dominant to ebony body color, while long wings are dominant to vestigal wings. Work the following corsses through the F2 generation and determine the genotypic and phenotypic ratios for each generation. Assume the P1 individuals are homozygous and that the genes for body color and wing pmorphology are located more than 50 map units apart on the same autosome.

	FEMALES		MALES
[a] P1	gray, long	x	ebony, vestigal
[b] P1	gray, vestigal	x	ebony, long
[c] P1	gray, long	x	gray, vestigal

1. How would you testify in the paternity trial outlined below? Explain your reasoning.

Mother	AB bloodtype
Child	B bloodtype
Husband	A bloodtype
Postal carrier	O bloodtype

Would you change your testimony if the new information outlined below became available? Why or why not?

Husband's mother	AB bloodtype
Husband's father	AB bloodtype
Husband's sister	B bloodtype

2. In garden peas, tall stem (T) is dominant over short stem (t), green pods (G) are dominant over yellow pods (g) and smooth seeds (S) are dominant over wrinkled seeds (s). Suppose a homozygous short, green, wrinkled pea plant is crossed with a homozygous tall, yellow, smooth one.

[a] what will be the appearance of the F1?

[b] what will be the appearance of the F2?

[c] what will be the appearance of the offspring of a cross of the F1 back to its short, green, wrinkled parent?

[d] what will be the appearance of the offspring of a cross of the F1 back to its tall, yellow, smooth parent?

3. In cocker spaniels, solid coat is dominant over spotted coat. Suppose a truebreeding solid-colored dog is crossed with a spotted dog and the F1 dogs are interbred.

[a] what is the probability that the first puppy born will have a spotted coat?

[b] what is the probability that if four puppies are born, all of them will have a solid coat?

4. In sesame, the number of seed pods per leaf axil and the shape of the leaf are each controlled by one pair of alleles. The one-pod (1) condition is dominant to three-pod (3) and normal leaf (w+) is dominant to wrinkled (w).

The results of 5 crosses, each between a single pair of plants gave the resutlts shown. Determine the genotypes of the parents of each cross.

Cross	**Parents**	**1,w+**	**1,w**	**3,w+**	**3,w**
1	1,w+ x 3,w+	318	98	323	104
2	1,w+ x 1,w	110	113	33	38
3	1,w+ x 3,w+	362	118	0	0
4	1,w+ x 3,w	211	0	205	0
5	1,w x 3,w+	78	90	84	88

Appendix V The Raw Data

This section presents the data collected from the pre- and post-tests for each unit in this study. The following coding was used to summarize the data:

column 1	topic [1 = unit 1; 2 = unit 2]
column 2-3	student identification number [01-90]
column 4	gender [1= male;2 = female]
column 5	academic standing [1 = low; 2 = mid; 3 = high]
column 6	treatment group [1= Group A; 2 = Group B; 3 = Group C]
column 7-9	post-test score [per centage]
column 10-12	pre-test score [per centage]

Unit 1 Data

Treatment Group A	Treatment Group B	Treatment Group C
101211075020	132222070040	168223085025
102221075040	133222065025	169223055020
103131090075	134132070035	170223085040
104211040030	135122095040	171123085020
105121060035	136132090035	172223070030
106121085030	137132100040	173223060100
107131095025	138232095070	174233080030
108211015000	139222055040	175233070040
109221055015	140232090025	176213050010
110221065035	141122080020	177223055035
111221060040	142122060040	178123090090
112211055020	143122060060	179133095040
113221090025	144122090045	180113090025
114121090010	145232060045	181223075020
115121080040	146212050045	182213055040
116231055050	147222060020	183223065040
117221065030	148232060040	184223060035
118121060045	149222055050	185223040040
119211000030	150222060030	186113015025
120221050040	151132085040	187223090040
121121025010	152212025030	188223085020
122131090000	153122075035	189213040020
123221055035	154222050030	190123040025
124221070030	155232050035	
125231050035	156132045010	
126121040040	157222065000	
127221055030	158212060050	
128231045035	159112090075	
129121060030	160122065010	
130121060030	161122075040	
131221055030	162222055040	
	163132050040	
	164132080045	
	165222045000	
	166222090045	
	167222075040	

Unit 2 Data

Treatment Group A	**Treatment Group B**	**Treatment Group C**
201211020040	232222090100	268223075020
202221085080	233222060080	269223030025
203131090070	234132080100	270223060070
204211030010	235122100095	271123085030
205121085025	236132100080	272223075050
206121090090	237132100100	273223065100
207131075070	238232100100	274233085050
208211030000	239222100050	275233090065
209221085025	240232095060	276213055000
210221070075	241122085080	277213055000
211221075080	242122025095	278123075090
212211035020	243122070070	279133080070
213221085080	244122090040	280113055015
214121090090	245232085090	281223050040
215121090090	246212085020	282213070045
216231065090	247222070090	283223045075
217221080080	248232090100	284223060025
218121070020	249222090100	285223020020
219211095075	250222060020	286113015065
220221085030	251132090100	287223070035
221121090020	252212075065	288223065050
222131055070	253122055070	289213045045
223221035020	254222070075	290123060075
224221085085	255232090065	
225231100095	256132060090	
226121020075	257222085075	
227221025070	258212075045	
228231090095	259112085020	
229121070015	250122090035	
230121065080	261122075070	
231221085090	262222060050	
	263132060090	
	264132095080	
	265222020010	
	266232090070	
	267222040010	