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COLLABORATION WITH STUDENTS AND TEACHERS IN GRADE 2 AND GRADE 5 TO DEVELOP COMPUTER-BASED LESSONS WITH SPEECH: A CASE STUDY

by

GEORGETTE LAMY, SEJ

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The Undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Collaboration with students and teachers in grade 2 and grade 5 to develop computer-based lessons with speech: A case study* here submitted by Georgette Lamy, SEJ, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

Although many current commercial educational software programs feature the use of digitized speech, no research has been done on student preferences for auditory presentations in computer-based learning. Parallel research has been done for adult preferences in a computer tutorial program and for pilots' preferences in flight training simulations.

This study focused on a grade 2 and a grade 5 class. Computer lessons were prepared in collaboration with the classroom teachers who determined content and learning objectives and with students who evaluated lesson design and made suggestions for revision and future lesson design. Computer records were kept of all student responses to choices of various aspects of auditory presentations. All lesson records were compiled to find class means in order to determine general preferences. Three students in each grade were chosen by the teachers to represent three levels of learning ability. These students were interviewed to provide insights into student choices and personal preferences. A final year-end class questionnaire provided all students with a voice in describing their individual preferences.

It was determined that the students in this study did enjoy having computers speak but they wished to control both the mode of presentation (visual or spoken) and the repetition and frequency of auditory presentations. With sound-intensive lessons, they preferred to have the option to use earphones to cut down on audio interference. Other preferences, such as preference of presentation mode for various uses in each grade, were investigated.

The experience of collaboration in developing computer-based learning had an effect on both teachers and students. The two teachers became more sophisticated in their ability to integrate computers into the curriculum. The students appreciated the lessons and, in some cases, expressed a renewed interest in a particular school subject.

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I have been enriched by the time spent in collaboration with the two classroom teachers, collaborating in the design of computer-based lessons to meet their needs and objectives. Working with them and experiencing the enthusiasm of the grade 2 and grade 5 students has been personally and professionally satisfying.

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CHAPTER 1

MY PERSONAL INVOLVEMENT WITH COMPUTERS

Looking back at how my understanding of educational computing has developed, I see that I have used computers in a manner related to major trends in hardware and software development at the same time as I have deepened in my understanding of education. As aptly stated by Alan Ellis in 1975, "thinking about computers in education does not mean thinking about computers, it means thinking about education" (Sewell, 1990, p. 2).

As I have taught computer science from 1974 to 1987, worked closely with the computer consultant of a school division from 1982 to 1987 and developed educational software from 1988 to the present, I am offering a personal view of the trends in educational computing and my concurrent growth in educational thought.

Mainframe Use in Education

In the early years of educational computing (1960's), computer-assisted instruction (CAI) lessons on mainframe computers were "delivered" to the student, and computer-managed instruction (CMI) kept records of objectives mastered and test results achieved (McMahon, 1988; Rushby, 1988). Examples of CAI on mainframes are the Brentwood Project (later called the Stanford Project after the university conducting it), the PLATO (Programmed Logic for Automatic Teaching Operation) Project and TICCIT (Time-Shared, Interactive, Computer-Controlled Information Television) (Atkinson, 1974; Eraut, 1989; Mason, 1980; Obertino, 1974).

These CAI and CMI programs used a didactic or centralist model (Barker, 1990; Collins, 1991; Purchase & Robinson, 1990). A team of experts pre-determined instructional objectives and behavioral goals, often using techniques of programmed learning advocated by Skinner (1965, 1984). Short incremental learning steps with positive reinforcement became a norm for drill-and-practice software (Poppen & Poppen, 1988). Streibel (1986) cautioned against the use of this deterministic software as it does not support non-behavioral goals and therefore does not lead to critical thinking or personal empowerment.

My first experience with computers was at a week-long Professional Exchange Mathematics Seminar in Regina, Saskatchewan in 1972. The seminar participants had the opportunity to access a remote mainframe computer in Toronto at a terminal in a

Regina high school. Here we experienced an elementary drill-and-practice exercise and played a game of blackjack. At this time I decided that, after teaching two years in North Battleford and checking into the cost and possibilities, I would propose to the school board the inclusion of a computer science course in our high school curriculum.

This is exactly what happened. In early 1974 I expressed an opinion that computers would become important in society and that our students should become conversant with them and their possible effects in society. The financial requirements and feasibility of offering an elective computer science course for our senior high school students were listed in a proposal with a request for funding for a first year university computer science course during the summer. They accepted.

Thus I began to teach computer science to a class of high school girls from grades 10 to 12. The course included computer literacy (a study of computer hardware and societal issues) and programming (FORTRAN). The students created simple programs and keyed them into computer cards for the University of Saskatchewan IBM 360 mainframe to read. As our classroom rented a single keypunch machine for the semester of the course, students had to sign up for individual use. After manually checking the program cards for syntax errors, I would take them to a computer reader on the Saskatoon University campus once a week. While waiting for the other teachers in the car pool to finish their night class, I would fix up minor syntax errors and re-run the programs.

For the repetition of the course in 1977, we used the North Battleford City Hall computer reader to access the Saskatoon University mainframe. Two students were trained to use it so that student assignments could be run daily.

As did other computer science teachers at this time, I perceived computer literacy as a separate discipline. I accepted the behaviorist learning theory and considered students to be passive recipients of knowledge. The teacher was the knowledgeable authority. If only information could be broken down into simple and small enough chunks and explained well, students should be able to learn anything.

Development of Microcomputers

Although the Alto by Xerox PARC was the first personal computer (Fraase, 1990), it was the commercial access to the Altair 8800 in 1975 that signaled the beginning of microcomputers (Nelson, 1987). The consequent development of commercial microcomputers in 1978—the Apple II, the Commodore Pet and the Radio Shack TRS-80—enabled computer prices to fall into the range of school board budgets. Computers became machines for ordinary people and schools rather than for only big business and government.

In 1979, I moved to Saskatoon to teach in a large high school in the Separate school system. The school had one Apple II microcomputer in 1979 and obtained another four in January of 1980. During the second semester of this first year, I taught non-credit short introductory courses in BASIC programming to drop-in students during non-scheduled times. During my second year, the course offerings expanded to a credit computer literacy and programming course. With three classes of students enrolled and five computers running, I thought we were rich indeed.

I taught computer science this first year of teaching with microcomputers in the same way as in the mainframe era, with lectures during class time and assigned individual computer time for each student. Over the course of the semester, many students lost their initial motivation and did not sign up for computer time. I therefore decided to change my teaching method.

The second year, the class was divided with half working at the computer in groups of three while the other half followed a lesson. Students were somewhat more motivated with the shorter lecture time and more available hands-on experience. Programming became more interesting than in the mainframe era because of the immediacy of computer response. However, my view of computer use had not changed fundamentally. Computer literacy was considered a separate discipline and the use of computers meant programming. Students kept dropping the class because they found programming difficult and uninteresting.

About this time, the Minnesota Educational Computer Consortium (MECC) software became available to our school as part of a district-wide license. I reviewed this software and demonstrated to other staff members those programs thought to be relevant to their subject areas. Because much of this text-based Apple II software was of the drill-and-practice variety, most teachers did not incorporate computer use into their lessons. Being more attracted to using the technology for its own sake, I considered these programs interesting.

During the years of teaching programming, I developed CAI programs for students to use in other subject areas: French, social studies, and geometry. My students enjoyed these programs, even though they were mainly of the drill-and-practice variety, because they provided a change from the regular classroom routine.

As a result of MECC and my own custom built CAI software becoming available, our computers were beginning to be used in other curriculum areas, but in somewhat rare cases. One teacher accepted to have his students review English grammar on the computer as long as I supervised the group working on the computer. The year that I asked him to supervise his own students' use of computers, his interest waned.

Another reason for a lack of teacher interest in using computers was the high student-computer ratio. Programming students were encouraged to use the nine computers during their unscheduled time. With a school population of 1600, there was not much available computer time remaining.

During this time, the upper elementary schools began to use LOGO, a programming language for the Apple II. Papert's aim in developing this language was to give students control of the computer and powerful tools "to think with" (Papert, 1980). He envisioned the use of LOGO integrated into mathematics and English with students using it in a discovery mode (Barrett & Paradis, 1988; Solomon, 1988). However, many teachers taught LOGO as computing, separate from other curriculum areas. It was not taught in a discovery method as in Papert's vision.

Computer as Tool: Computer Applications

It was in the mid-1980's that a major shift in computer use occurred. Although a spreadsheet program, **VisiCalc**, and simple word processing programs had been available since the early 1980's, teachers now began to broaden computer literacy to include computer applications: the use of computers as tools (Hancock, 1989; Hoot & Kimler, 1987; Kurshan, 1986; Roberts & Mutter, 1990; Rodgers & Bonja, 1986). This was a shift in the perception of computers from delivering instruction to being a learning tool. Papert had already called in 1980 for the shift from having computers control children to children controlling computers (Papert, 1980).

WordPerfect, **SuperCalc** and **DBase II** were being used on our 19 new MS-DOS machines, acquired in September of 1984, and an experimental project to use a modem to access remote databases was begun. Using computers in this way was much more interesting to students than simply programming, although BASIC was still taught. The applications provided more variety and students enjoyed achieving visible results.

The business education teacher and I worked to incorporate computers also into the secretarial and office procedure program. This meant that educational computing was finally expanding to other subject areas rather than remaining enclosed in a separate discipline.

Meanwhile in 1985 my school expanded the computer science program to grade 12 to include programming in Pascal. After two years of struggling to teach grade 12 computer science to small groups of students, mainly males, who could learn techniques more quickly than I, I felt a need to have a firmer understanding of educational computing, both in content knowledge and in teaching strategies. I took a year's leave of absence in 1987 to begin a Master of Arts program in Computers in Education at Simon

Fraser University, Vancouver, B. C. Meanwhile, computer hardware developments were again providing the possibility of another paradigm shift in educational computing that would turn out to be as great as that of the introduction of the microcomputer itself.

Graphics User Interface

The development of the graphics user interface (GUI) on the Xerox Star computer in 1982 was the next breakthrough in permitting people to access computers more easily (Edwards, 1991). This interface included windows and a pointing mouse first conceived by Doug Engelbart in the 1950's and 1960's (Engelbart & Hooper, 1987). The first commercially produced computer to implement this interface was the Apple Macintosh. Released in 1984, the Macintosh was not taken seriously at first (Nelson, 1987), perhaps because of this novel interface.

While studying for a Master's degree at Simon Fraser University, I learned the graphics user interface on the Macintosh and on IBM computers with Windows at an educational computing center there. For two years I explored the possibility of creating information-delivery modules with another important computer development, hypertext, now being bundled with each Macintosh in the form of **HyperCard**. Equivalent programs for MS-DOS computers were **IBM LinkWay** or **Toolbook**.

Hypermedia

The inclusion of **HyperCard** with each Macintosh in 1986 brought the idea of hypertext to the forefront while the Macintosh's word processing and graphics ease heralded present desktop publishing. Although Vannebar Bush had conceived the idea of hypertext in 1945 and Ted Nelson named it in 1967, it only caught on in 1986 (Bush, 1986; Fraase, 1990; Barrett & Paradis, 1988; Conklin, 1987; Nelson, 1987).

Within a short time, computer technology was improving to enable computers to control the access of information in different modes. The idea of hypertext expanded to include other media, called "hypermedia" (Conklin, 1987). Computers now control equipment to deliver or access information in video, audio, animation, graphics and text mode (Ambron, 1987, 1990; Carr, 1988; D'Ignazio, 1989; Denning, 1989; Fraase, 1990; Gano, 1987; Hooper, 1987, 1990; Megarry, 1988).

Although each new stage of educational computing has had its roots in the previous stage, each new capability presents possibilities to make a further step in the evolution of educational computing. For example, after about five years from the development of microcomputers and application software, teachers began to shift from the use of CAI and from computer programming alone to the use of application tools. As teachers became familiar with new capabilities, including hypertext and hypermedia, new educational uses were developed (Bordier, Paquette & Carrier, 1990; Campbell, 1989; Crane & Mylonas, 1988; Friedlander, 1987; Ropa, 1991) that shifted our view of educational computing.

Although hypertext and the related idea of hypermedia were viewed as a teacher tool for creating instructional materials, the initial novelty of its use wore off and browsing through information was not captivating in itself. It was the expression of creativity that was motivating and engrossing, not browsing through or even interacting with other people's work, however interesting.

At the same time, my becoming an adult student forced me to reflect on what teaching and learning meant. I began to experience a paradigm shift. I no longer saw myself as a passive recipient receiving instruction. I had to be personally engaged in this enterprise. This led me to embrace the cognitive learning theory in which the student is an active and responsible agent (Condry, 1977; Cronbach, 1966; de Charms, 1968; Lacey, 1979; Langer, 1980). I accepted Tolman's theory of learning in which purpose plays an important role and cognition is a significant explanatory variable even though it cannot be directly measured (Hergenhahn, 1988).

In relation to educational computing, this tells me that students should have control of the computer, using it to achieve their objectives and goals in a constructivist learning environment (Collins, 1991; Kinzie, 1990; Sewell, 1990; Strickland, 1989; Thompson & Jorgensen, 1989). Some experiments have shown that not all students can make wise choices in computer-based learning (Gay, 1986; Goetzfried & Hannafin, 1985; Gray, 1987; Kern & Khalik, 1988; Steinberg, 1977; Tennyson, 1980, 1981). For this reason there must be some guidance or direction in the exercise of this freedom. With this direction, researchers have shown that there is more learning (Hannafin & Colamaio, 1987; Harris & Cody, 1988).

Computers are well suited to being used in this environment as they are a unique medium not limited to one type of content, one symbolic mode of representation, or one style of activity (Salomon, 1988). He suggested that computers are the only technological medium (besides teachers) that can interact with students and extend or amplify their mental capacities.

If computers with suitable software are placed in a classroom with a didactic educational environment, they have an effect on that environment (Sandholtz, Ringstaff & Dwyer, 1990). They encourage independent exploration and team work and discourage didactic instruction (Salomon, 1988). In the presence of a high-technology environment, teaching changes to a more individualized learning style in which a teacher becomes a facilitator and a guide rather than the authority and repository of all knowledge (Collins, 1991; Sandholtz, Ringstaff and Dwyer, 1990).

Educational computing is the empowering of students to use whatever technology and software they need to achieve their goals. A structured environment needs to be provided so that students can determine personal objectives and goals. These have to be negotiated in order to be in line with our culture and educational policies. Students still need guidance and structure (Collins, 1991; Dwyer, 1980; Fisher, Blackwell, Garcia & Greene, 1975; Gay, 1986; Goetzfried & Hannafin, 1985; Gray, 1987; Hannafin & Colamaio, 1987; Stipek & Weisz, 1981; Tennyson, 1980, 1981).

Computers are now being perceived less as teaching machines and more as learning machines (Barker, 1990; Eraut, 1989; Lepper, 1985). As a result, students can begin to use computers for presentation and for communication; presentation, to display electronically the results of their research; and communication, to interact with students at the computer beside them or half-way around the world (Jones, 1990). After students learn to use hypermedia for presentation, it is an easy step to use it for information acquisition and data manipulation (Anderson, Oppenheimer & Fullan, 1992).

There are many technical and educational problems inherent in using computers in educational settings. The first is providing experimentation time. Hypermedia programs are not as easily mastered as software vendors suggest. All applications programs take time to master.

A second, more technical, problem is to match computer hardware and software and computers with computer peripherals. Software will not run well on some computers, even though they may be presented as compatible. Computers and their peripherals are not standardized and a particular hypermedia computer peripheral may not work on a specific computer.

As well, there are several educational problems for implementation of effective educational computing. The first one is the lack of an educational vision (Zappone, 1991). There is confusion of objectives in the use of computers. A second one is the lack of teacher training. Teachers have to develop a minimum level of comfort with computers before they can integrate them into their classes. This is difficult to achieve as teacher time and energy are limited.

A third major problem is a lack of suitable hardware. Since most schools do not have sufficient funding to continually provide up-to-date equipment, students continue to use computers bought several years ago (Borrell, 1992).

A fourth and serious problem is a lack of suitable software. All proponents of educational computing assume that the school can provide a minimum standard of varied and interesting software. Students must have access to word processing and graphics programs at the very least. Databases, spreadsheets, desktop publishing, educational games, simulations, tutorials, and even drill-and-practice exercises of essential rote skills are all useful. Students must have an information-rich computing environment in varied modes or the computer will only be used to further the textual predominance of the textbook and lecture era.

A final educational problem is a lack of suitable research. Much of the previous research has been aimed at comparing an instructional method delivered by computer to one delivered by a teacher (Torkelson, 1986). This research forces each delivery to be constant so that only the medium varies. There is no use investigating the advantages of a computer text display to printed text as the computer's appeal lies in the differences of its features (Willis, 1991). Computers are interactive and responsive to students. What should be investigated are the characteristics of the media, what variables are preferred by students, and how they are interpreted by them (Torkelson, 1986).

This last need encouraged me to study one specific way in which computers can be used more effectively. I had become interested in the inclusion of speech in computer use now that technological development makes this feasible. The computer should not be a mute partner in interaction with children. The verbal symbol system can now be presented on computers in audio mode as well as in textual mode.

Following from my acceptance of the cognitive learning theory that considers students active agents in their learning, I wished to provide elementary school children with computer-based lessons that would incorporate student control by giving them choices. Student control was seen to be the ability to determine some aspects of the lesson by making choices. These choices could be: accepting a default setting or changing it, determining a route through a lesson through menus, or asking for one or another type of presentation. Student control is determined by the number and type of choices permitted by the computer lesson designer.

Combining this with the recent possibility of including speech in computer-based lessons, I wished to determine if students thought that speech was an important characteristic of a computer lesson and if so, for which types of uses. To arrive at this, auditory material first had to be provided to the students so that they could experience it and compare it to viewing text material only. Then students had to be provided with choices between the visual and the auditory modes so that their choices indicated their preferences. Although their audiovisual preferences would not necessarily indicate their acceptance or non-acceptance of speech in computer-based lessons, a strong preference towards the auditory mode would indicate the importance of including speech in these lessons while a strong preference towards the visual mode would indicate the non-importance of providing this alternative mode.

The focus on student preferences may indicate a value judgment, that these preferences are seen to be necessarily good. Students may and do adapt to various situations and must expand their capabilities in all directions. However, when a choice is between two equally acceptable realities, a decision to follow a preference is admissible. If deaf students choose the auditory mode, their choices could be considered absurd and could indicate that the choices are not animated by an intelligent decision. Recording choices is useful if students make intelligent choices based on what is most helpful for them and on a desire to learn. In the context of school-based research where lessons are integrated into the school curriculum and related to what they are learning, students may be more inclined to see the lessons as part of their learning. As agents in their learning, they can then take the responsibility to make the best use of these lessons they can. In previous research, I found that even young students are generally able to make choices that reflect their perceived needs and their desire to learn (Lamy, 1990, 1994).

Although the research focused on student preferences, it was not examining a simple preference between perceptual learning styles. Students may prefer one or more of the seven perceptual learning styles (print, aural, interactive, visual, haptic, kinesthetic and olfactory) as a personal style of learning (Higbee et al., 1991). The computer lessons required the use of the interactive mode and always contained visual material that was presented either graphically or textually. At times, students chose between additional textual material and auditory material to accompany this visual material. At other times, the choice was whether to receive auditory support of textual material or not. The focus was not only on receiving material by a preferred mode but also on the acceptability and importance of including auditory material in a computer-based lesson.

Many areas of knowledge needed to be explored to prepare for a study of this scope. Because the study was based on student preferences, it seemed important to examine the information-processing approach, with its acceptance of the processing power of the mind under the control of the person and its explanation of visual and auditory perception. Another area examined in relation to the latter was research on the development of perception and on multichannel perception. Because of the use of computers in the study, a survey of the various ways sound and speech have been used in education, television and computers provided background in determining which aspects of text and auditory presentations needed to be included in the study. The next chapter will contain the various literature reviews.

CHAPTER 2

INVESTIGATING THE LITERATURE

THE INFORMATION-PROCESSING APPROACH

The information-processing approach has been spreading through the field of cognitive development during the last two decades. Miller (1989) pointed out that many developmental psychologists who study memory, attention, and problem solving accept certain assumptions and methods from the information-processing approach without awareness of their sources.

Historical Development

The information-processing approach developed through adult experimental psychology before being used in child developmental psychology. Adult experimental psychology changed as a result of two developments in the 1940's and 1950's. Many psychologists lost confidence in neobehaviorism's verbal-learning research, especially when it was attacked by Chomsky in his 1959 review of Skinner's book, *Verbal Learning* (Miller, 1989, p. 275). The second development was an increasing attraction to computer technology and programs that seemed to simulate human logic (Newell & Simon, 1961).

The Symposium on Information Theory, held at the Massachusetts Institute of Technology on September 10-12, 1956, marked the beginning of cognitive science. On the second day of this Symposium, Allen Newell and Herbert Simon described the proof of a theorem that had been derived by a computer in the paper "Logic Theory Machine" and Chomsky described his "Three Models of Language" in which he described "his own approach to grammar, based on linguistic transformations" (Gardner, 1985, p. 28).

As a result of these shifts, psychologists, unlike the behaviorists, were now willing to talk about the mind. Miller (1956) suggested that humans could remember approximately seven chunks of information in their immediate memory. Broadbent (1969) stated that humans have a limited processing capacity so that less important information must be filtered out before sending the information to higher levels for further processing. Peterson and Peterson (1959) provided some support for the suggestion that there are two kinds of memory states: short-term memory and long-term memory. Miller, Galanter, and Pribram (1960) suggested that humans use strategies to solve problems. Later researchers (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965) proposed that information moves through some distinct stages in which attention and memory are involved. Craik and Lockhart (1972) claimed that memory should be considered as levels of processing rather than separate stages. The same stimulus can be considered from many viewpoints and in so doing, deeper processing occurs that requires more attention and effort.

Orientation of the Research

Today, information-processing research encompasses varied activities. Not a single theory, information processing is a framework that describes a large number of research programs in which researchers study the flow of information through the cognitive system. The flow begins with input (stimulus) and ends with output (overt or covert behavior). Between the input and the output are mental processes that can be compared to a computer's processing. These processes act on the input, perform operations on it and store the results. Researchers adhere to this computer metaphor at several levels but it has served as a valuable heuristic for developing the field of information processing.

The information-processing approach differs from Piaget's developmental learning theory in that Piaget was interested in how a new concept fits into a child's overall cognitive structures while the information-processing theorist is interested in how the processing system operates in a particular situation. The information-processing theorist studies how a particular stimulus is encoded into a cognitively useful form, then processed and stored for use in the task at hand.

As previously mentioned, the computer metaphor is accepted at several levels. Thomas (1992) mentioned only two levels but Klahr (1976) described three levels of computer use in the information-processing approach. In level I, computer programs were designed to portray and explain cognitive behavior for a specific and narrowly defined task such as playing chess or checkers. At level II, the information-processing models could portray and explain basic mechanisms used in a wider range of problems. The emphasis here was not so much on a computer program but on a description of the cognitive tasks in terms of symbolic representations and processes that operate on these representations. At level III, the computer was considered only as a metaphor of the human information-processing system.

David Klahr (1976) maintained that the unique advantages of the information-processing approach disappeared in level III since computer operations could not then be taken as a visible model of human cognition. But Thomas (1992) pointed out that the level I theorists made an assumption that if a computer program were given the same problem-solving input as a human and if the program produced the same output, then the intervening computer operations may have contained the same sorts of components and processing steps as those found in the human nervous system.

Since there are many ways of acting on input to achieve a comparable output there must be some criteria to humanize the intervening computer processing. To be somewhat more plausible as a psychological theory, Simon (1972) offered the following constraints: "(a) consistency with what we know of the physiology of the nervous system; (b) consistency with what we know of behavior in tasks other than the one under consideration; (c) sufficiency to produce the behavior under consideration; and (d) relative definiteness and concreteness" (p. 18-19).

These constraints somewhat temper the basic assumption that a computer program can model human cognition. It is this assumption that I find unacceptable, since humans are much more complex than a purely logical device. Humans do not make binary choices; the emotional dimension can create new possibility of choices. "I don't care", "I don't want to choose now" or "I choose the illogical choice because..." are human statements. Motivation and emotional states play havoc with the pure logic of a computer-modeled cognition.

Although the informati processing approach does not seem to allow for human illogic, much of its explanation of human cognitive processes can be appreciated. The next part of the paper will describe the main aspects of the information-processing framework with a description of the manner different theorists view human processing.

Elements of Human Information-Processing

The classical theorists considered human information processing to have four elements: the sensory organs, short-term or working memory, long-term memory, and the muscle systems energized by nerve impulses to perform motor acts. Tennyson (1992) presented an interesting model that added both executive control and an affective component. I will examine each of the four elements of the classical theorists and the two additional elements of Tennyson's model.

Sense Organs

A person receives information about the world through the senses—eyes, ears, and pressure receptors under the skin for touch. Other organs detect smell, taste, temperature, pain and body position. Each organ collects stimuli in a narrow band and may filter this information before passing it on to the human processing system. Klatzky (1975) included control processes, pattern recognition and attention, whose function was to get the information to deeper levels. Pattern recognition converts raw information into something meaningful. Selective attention allows only important information through, to be brought into the limited-capacity system known as short-term memory.

Short-Term Memory

The original conception of short-term memory was developed by Atkinson and Shiffrin (1968). They saw it as a limited capacity, short-term store that had to be maintained by rehearsal or else new information entered to displace former items. Their model was that of a static store but further development of the short-term memory model lead to a dynamic store.

There has been controversy over the division of memory into a short-term memory and a long-term memory. Some researchers such as Craik and Lockhart (1972) preferred viewing the two types of memory as different levels of processing but newer neurophysiological data point to a dual-system model (Dempster, 1985).

The short-term memory may be divided into three stages: a specialized memory for each sense for momentary image retention (iconic memory for visual memory, echoic for auditory and haptic for the touch senses), an encoding stage for each sense and finally a semantic short-term memory in which the coded materials from all the senses are combined into perceived information for long-term storage.

George Sperling did the seminal study in 1960 on visual memory with experiments of immediate-memory tasks in which people viewed a few letters for a short time span of 50 milliseconds (Klatsky, 1975; Schiffman, 1990). Subjects could remember four or five letters accurately, but no more than that. Yet if they were asked to report on only one letter, being given its position in the array after having seen the array, or three letters in one row of the array, they could remember any one of nine letters. Subjects lost accuracy as the time before these partial one-letter reports increased until at 1 second, they reached the same performance level as when they were asked to report all the letters. This type of visual memory was named "iconic storage" by Ulric Neisser in 1967 (Schiffman, 1990).

Moray, Bates, and Barnett (1965) studied "echoic storage" and found that people could discriminate among four sources of sound at a time. As they listened to four channels, they were asked to remember all or some of the letters. Similar to the "iconic storage," the "echoic storage" held the letters long enough that more accuracy was achieved for partial reports of a list of only those letters coming from one channel (i.e., up to four letters) than for full ones of a list of all the letters. Darwin, Turvey, and Crowder (1972) found that "echoic storage" lasted for about 2 seconds before subjects became less accurate.

Because echoic storage must receive auditory stimuli in a linear fashion and short-term memory can hold only up to seven chunks of information at a time, this 2-second limit becomes important in determining how much auditory information can be presented at a time. Although sentences that will be read can be quite long, sentences that will be heard must be short. There must be completion of the thought within the 2-second limit. The adult's greater experience can help to combine meaningful phrases into larger chunks than a child can and the adult's vocalization speed can permit more words within a shorter time. Thus, children's 2-second limit will contain fewer words than an adult's 2-second limit.

Klahr (1976) gave the name of buffers to the short-term memories used for each sense. This was from the computer term referring to a small memory storage space used for quick processing. Thus, his model is called multiple buffers.

Information from short-term memory is encoded in some form in order to place it in long-term memory. One question that arises is whether there are more than one type of representation possible. Shepard (1967) showed subjects 2,560 slides for 10 seconds each. Since they scored 90% on a recognition test a short time later, there must be some picture-like information stored in the memory. Frost (1972) used 16 drawings of common objects that could be categorized on a semantic basis (i.e., animals, clothing, vehicles and furniture) or on a visual basis of one of four orientations (i.e., vertical, horizontal, slanted left and slanted right). Those subjects who were led to expect a recognition test clustered the images in a free-recall test in both semantic and visual characteristics. Those subjects who were led to expect a free-recall test on object names clustered them on semantic characteristics. This would lead to the conclusion that those who expected a recognition test stored the images in long-term memory. This dual coding can be very useful for children as a memory strategy to recall concrete aspects of a story. If they can create an image of each sentence of a story, they have a better chance of recalling details later.

On the other hand, Pylyshyn (1973) pointed out problems with the concept of visual memory. If pictures are stored in exact form, we would need unlimited storage space to store varied visual scenes. Retrieval from stored pictures would require re-perceiving and analyzing the picture. Pictures could not be retrieved by a single word because many pictures could be retrieved by any one word. Furthermore, Klatzky (1975) described an unpublished study by Bower, Munoz and Arnold in 1972 who asked subjects to pair sentences with words at times and with images at other times. Since subjects could not remember which strategy they had used, Bower suggested that people form semantic relationships rather than mental pictures.

The following exercise demonstrates effectively a possible relationship between visual and semantic memory.

> Memory exercise:
> "In the house in which you lived three houses ago, how many windows were there on the north side?" (Rumelhart, Lindsay & Norman, 1972, p. 199).

Normally people go through a systematic visualization of their present house, count back three houses, imagine the north side of their house, and then count the windows. Depending on the manner people use to determine the answer, this exercise can demonstrate that people determine a process to arrive at the solution, use it and find factual information about the structure of the house in the database. Even though there may not be an "image" held in long-term memory of the north side of that house, it can be reconstructed.

The visual-semantic controversy is an old one in psychology but two points can be made about visual memory. One is that the world cannot be represented in long-term memory in full detail; the other, that there is some information about visual events stored in long-term memory. What is uncertain is how much the visual information stored in long-term memory resembles mental pictures.

Long-Term Memory

All stages of short-term memory and even the filtering of the senses are continually interacting with long-term memory. Long-term memory, to the information-processing theorist, is the rest of the processing system, including the mental constructions forming the knowledge base, the person's goals, interests, motivation, and emotions, as well as stored memories of events and processes.

It is this part of the system that controls and interacts with all other parts, filtering out irrelevant information, paying attention to those aspects of the environment that are of interest, combining the sensory images into a recognizable perception, and assimilating new information into the knowledge base.

E ncoding example:
Suppose we read the following paragraph to a subject:
"The pitch came in over the plate. Everyone heard a loud 'crack.' In an instant, the ball sailed over the fence." (Kail, 1990, p. 84).

If the subject were asked to repeat the paragraph after a short pause, we would probably hear about a pitcher, a batter, and a home run. The subject will have made inferences from the material.

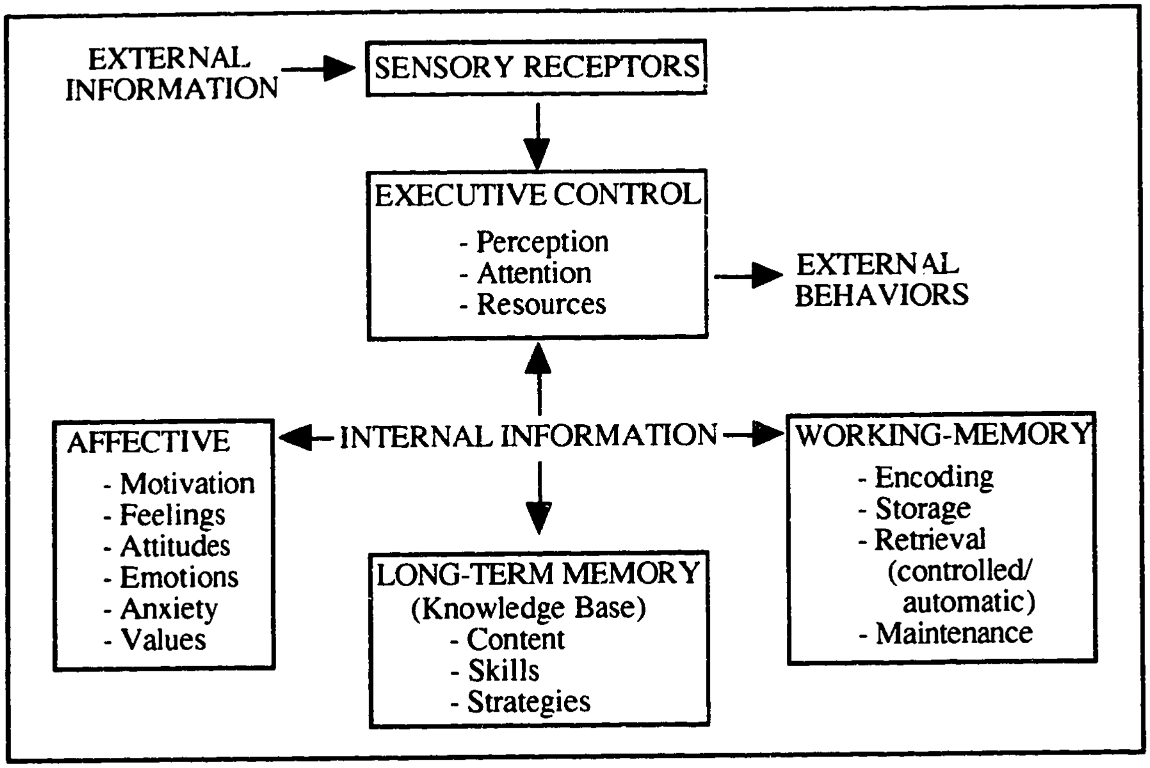
Tulving (1972) distinguished between episodic and semantic memory as two information-processing systems. Episodic memory stores information about an event and temporal-spatial relations among events. This event is something that has happened to the person. Semantic memory is necessary for the use of language and stores information about words, their meaning, relations among them, and concepts. Information may enter semantic memory either through perception or thought. In 1985, he proposed a three-tier system with procedural memory common to all three tiers, semantic memory as a subsystem of procedural memory and episodic memory as a subsystem of semantic memory (Snodgrass, 1989).

The above encoding example demonstrates encoding of the sense of the words into semantic memory rather than encoding the words themselves into episodic memory. The subject may encode into episodic memory the fact that a paragraph was to be remembered and encode the association of the researcher and his/her feelings about the situation with that particular event.

Classical theorists include affectivity or emotions by stating that each item stored in long-term memory has multiple strands connected to it, such as an affective or emotional component. Abstract ideals can have attached values. Thus, the structure of long-term memory contains a great deal of complexity. It is this complexity that has attracted many information-processing theorists as well as the question of how information is retrieved from long-term memory.

In the previous discussion, most of the theorists have placed cognitive strategies into long-term memory. Tennyson (1992) developed an integrated knowledge and strategy-based model that included two further components: executive control and an affective component (See Figure 1).

Figure 1 Tennyson's (1992) Model of Cognitive System for Educational Learning Theory



Executive Control

Executive Control regulates all other components of the information-processing system either actively or automatically through executive functions. The executive functions Tennyson presents are perception, attention and resources. For him, perception directs attention and determines the amount of effort to be expended; attention maintains a dynamic relationship with the working-memory; and resources coordinate the various components of the entire system. Executive Control also determines behavioral output (i.e., automatic or conscious activities).

Affective Component

Practicing teachers recognize that students are not simply cognitive beings. The students' emotions, motivation, feelings, anxiety, attitudes and values play a large role in perception, in attention and in the management of processing resources as well as in the effort expended for processing material in working-memory. Thus the affective domain interacts with both executive control and short-term memory. Tennyson's model provides an affective component to recognize the interaction of the affective domain with the cognitive domain.

In summary, sensory receptors, executive control, short-term and long-term memories and the affective component are the components of a human information-processing system. Before looking at research on the use of sound in learning, we will look at research on visual and auditory perception.

Research on Perception

Gibson (1966) viewed the senses as systems for perception, using the meaning of the verb "to sense" as "to detect something" (p. 1). He differentiated between a stimulus to the nervous system, or sensation, and the detection of stimulus information, or perception. The former occurs within the sensory receptors while the latter occurs within the executive control component. The ability to detect information from the stimulus increases with experience. What children do as they develop is to isolate and differentiate information that could not be initially detected. What is then encoded in long-term memory are the specific features or feature combinations that differentiate one object from other similar ones.

Since perception is so important in learning, it has been studied at all levels of human development. Of particular interest is the neonate's perception. Infants must learn about their environment chiefly through their senses. Young infants' perception has been studied by measuring responses to visual or auditory stimulus. These measurable responses are looking patterns, sucking patterns and heart rate patterns.

Looking patterns are determined by watching the infants' eyes. Preferences between images are often judged by how often a baby looks at one versus the other or the total fixation time to each of the stimuli. Fantz (1961) devised a simple method of looking through a peephole at the child's eye to record the amount of time the target was reflected on the child's cornea.

Brazelton and Cramer (1990) stated that babies sucked in a somewhat regular pattern of bursts and pauses. The rate of non-nutritive sucking averaged to about two sucks per second while bursts were grouped into 5 to 24 sucks per burst. Pauses between bursts could be prolonged if babies were attending to interesting stimuli.

There are some problems in using these measures. Young infants' physiological states can change over time and their ability to prefer some stimuli over others shows that they can discriminate but a lack of discernible preference does not necessarily mean a lack of discrimination. Other measures that were used were the brightening about the eyes, denoting an alert state in the infant, and the maintaining of a stilled posture (Brazelton & Cramer, 1990).

Unless specifically referenced, the following information is taken from Flavell (1977). Infants have poor visual acuity, poor binocular convergence and inflexible visual accommodation at birth, yet can see and follow large, moving stimuli. Those stimuli that attract the most attention seem to be those with the most contour. Cohen (1982) listed the results of visual experiments and stated that infants preferred curved lines, chromatic stimuli, three-dimensional objects, complex patterns and faces. Fantz (1961) found that infants preferred sharply contrasting colors, larger squares and medium brightly lit objects. He and others found that the neonate was attracted to the shiny eyes, red mouth and face edges in a picture of a human face but that a three-dimensional face was preferred.

As infants grow older, they can direct their gaze voluntarily. Movement and amount of contour still influence visual selectivity, but experience stored in memory begins to play an increasingly important role.

Two-month-old babies discriminated depth when placed on the deep side of the "visual cliff" invented in 1961 by Walk and Gibson, although what the infants interpreted was unknown. Six-month-old babies' heart-rate accelerated if they were placed on the deep end.

The neonate can hear sounds and is startled by loud, sudden noises. Brazelton and Cramer (1990) stated that neonates preferred the female voice, brightening and turning toward it. Horowitz and her co-workers (1974) found that two-month-old babies could discriminate between their mother's voice and a female stranger's voice reading the same passage.

Young infants are born equipped with a highly developed nervous system with an excellent auditory capacity. Spieker (1982) stated that one-day-old infants moved in rhythm to spoken language. Eisenberg (1976) determined that neonates preferred sound in the human speech range of 500–900 cycles per second with a distinct preference for the female voice. Morrongiello (1990) stated that infants could discriminate basic auditory features such as a change in frequency, intensity or large spatial displacements. Spelke (1979) demonstrated that four-month-old infants could relate an auditory stimulus synchronized with a visual object. He showed that young children could use intermodal information to guide investigation of their environment.

Although infants display visual and auditory selectivity almost from birth, it is cognitive development that will permit them later to select stimuli with meaning and purpose. Field (1987) stated that three-month-old infants began to locate sounds more reliably and motorically more efficiently.

Yet there is always a preference for the visual over the auditory (Field, 1987). Adamson (1977) demonstrated the importance of sight to the neonate. She covered a baby's eyes first with an opaque shield and then with a clear shield. While the opaque shield covered the baby's eyes, the infant attempted vigorously to remove it and quieted instantly when it was removed. Yet the baby calmly looked through the clear shield. This heavy reliance on visual information continues with even six- to nine-month-old infants showing more dependence on visual rather than auditory guidance in locating an object. Although children beyond the second year can use spatial information presented auditorily, this preference for the visual will remain a characteristic of human space perception.

At age three, children's selective attention begins to control their inner world as well as the outer one. They can attend to things before, during and after their perceptual presence. Knowledge becomes less reliant on the sensory mode as the senses become integrated. The essential information from the perception is encoded into memory in a more abstract and amodal form.

As children develop, they become more able to direct and control their attention, focusing on what is perceptually relevant to their objectives while disregarding what is irrelevant. They are better able to adapt their perception to what is required in a situation. For example, one situation may require focusing on only one feature while another may require focusing on two features. Older children can plan their perception strategy. For example, in comparing two pictures for similarities, older children will determine a systematic pattern for comparing all aspects of the pictures. Finally, older children can use their ability to control, adapt and plan their attentional perceptions in a task that spans a certain amount of time. They use an attentional strategy while it works but change it when it becomes inappropriate. They review previously scanned material to see if they missed anything and avoid hasty decisions based on incomplete sampling of the information.

The information-processing approach, even with its somewhat misleading computer metaphor, provides us with useful models with which to study human cognition. Much research has been done on human memory, although much of it has focused on episodic memory through the memorization of lists of meaningless words or of visual and auditory patterns. Much has been discovered about sensory perception and about short-term memory.

The interesting aspect of human information-processing is the aspect of controlled attention. Tennyson's cognitive model gives importance to the affective component that dynamically influences attention, perception and the management of resources in the executive processes and the effort to be expended in working-memory. In other words, the human information-processor deliberately chooses, from a very early age, to focus on those stimuli that answer to an internalized goal. This is done at every level of processing, from directing attention to particular stimuli, filtering out irrelevant data, and giving full, cognitive attention only to the desired portion. This controlled attention is at the heart of the educational enterprise and requires that the child be recognized as a subject rather than an object; an actor, rather than a passive recipient. It then becomes important in a research study on perception to examine what appeals to the child, what attracts this attention and what are the child's motives, feelings and attitudes.

Because the computer is going to be used as a presentation and manipulative medium for this study, it is also important to examine present technological capacity and current auditory research.

SOUND IN COMPUTER-BASED LEARNING

The Information Age is having profound effects in all aspects of society. In the area of media, we can observe a shift from a visual orientation to an auditory one. Rather than read magazines and newspapers, many people prefer to listen to the evening news on TV. Some students prefer seeing a movie or watching TV to reading a book. Many parents encourage their preschool-age children to watch *Sesame Street* to learn the alphabet and number symbols. This shift was already recognized in 1969 by Marshal McLuhan in his book, *Counterblast*, when he said: "When information is simultaneous from all directions at once, the culture is auditory and tribal, regardless of its past or its concepts" (McLuhan, 1969).

It then becomes important for educators to investigate the use of sound in its various aspects: for communication, for seizing attention, for enhancing visual stimuli and for relieving overload in the student's information-processing system.

Educational Uses of Sound

Although teachers use oral speech in much of their teaching, most elementary school teachers do not realize how much of the school day students are expected to listen. In a 1950 study, Wilt discovered that teachers estimated that children learned by listening only 74.3 minutes in a 270 minute day while observations showed that they listened 158 minutes, of which 54% of the time was listening to the teacher speaking (Wilt, 1950). Practically then, speaking and listening are the most widely used means of communication in the classroom.

Sound has particular characteristics that make it a unique sensory stimulus. Our auditory sense is omni-directional and is always ready while our visual sense is uni-directional and may not be ready or may not be capable of picking up the stimulus in a lightless environment. The siren of an ambulance usually attracts our attention before we notice its flashing lights.

Responding to sound seems to be an instinctive reaction. Even very young infants will respond to sound by turning their heads to its source. It may have been an important survival trait in the evolution of human beings. Since sound instinctively attracts, it has an educational importance for directing students' attention.

However, it is not in looking at our auditory sense in isolation that we will realize its full potential for communication. We are capable of receiving stimuli through many sensory channels concurrently and each sense image complements and enhances the other in forming the gestalt or full image. We feel a kitten's fur, hear its purr, see its form and facial expressions, and smell its distinctive odor. Both the visual and auditory stimuli give us feedback on our way of handling the kitten and tell us more about the kitten as a unique member of its category. Leaving out information from any sense would impoverish the resulting concept formed of kittens.

This interaction of visual and auditory stimuli affects the quality of our listening skills. Only a part of the information we receive when we interact with people comes from the meaning of their words. The tone of their voice, their facial expressions and their body language convey a great deal about their emotional and psychological state. Both visual and auditory stimuli and the information perceived through their interaction tell us about our environment.

Research on Multichannel Perception

This study will follow the relationships between information perceived through simultaneous channels proposed by Hartman (1961b):

> (a) "redundant information": the same word, printed and spoken, (b) "related information": a pictorial representation and a verbal description of an object, (c) "unrelated information": e.g., a picture of a tree and the spoken word, *nine*; and (d) "contradictory information": e.g., the simultaneous presentation of a printed word, *woman*, and a spoken word, *man* (p. 242).

An examination of educational television research may be seen by some as inappropriate for a study of educational computing. However, even though some aspects of television are more specific to that medium, new technological developments now permit computers to present both video and audio, in effect, to take on the persona of the television. Those research studies that examine multichannel perception in connection with educational television are, therefore, applicable to the creation of principles for an effective use of video and audio on the computer.

However, computers have unique aspects as well. The use of much text is not appropriate for television production (Hanson, 1989) as the viewer has no control over pacing or presentation direction. The computer user can control pace and may be able to review previously viewed textual material. This presupposes both that the programmer has provided user-control and that the student uses this control (Salomon, 1986). The computer's interactivity may also give its user greater control, for example, to obtain further information or to study schematic drawings in more depth.

Referring to redundant information—related information according to Hartman (1961b)—presented through any media, Shavelson and Salomon (1985) stated that the redundant encoding of the same information into two symbol systems "may provide more complete knowledge than if only one symbol system had been used" (p. 4). If we see a picture that we graphically encode and hear an explanation that we verbally encode, we are better able to comprehend both picture and explanation. This follows from the information-processing approach that states that more learning occurs with a greater processing depth.

Although the child's information-processing ability remains constant no matter which medium is utilized, the child brings different goals and a distinct view of that medium that will affect the effort and attention invested in the activity (Salomon, 1984; Salomon & Gardner, 1986; Salomon & Leigh, 1984). Thus, with this reminder that television and computers are each unique media and that research results using one medium may not necessarily transfer to the other, it may still be useful to examine multichannel perception research that used television.

Educational television has been a rich source of multichannel research to investigate if related audio and video enhances learning. Gibbons, Anderson, Smith, Field and Fischer (1986) supported this view in their study of 4.5- and 7.5-year-old children's recall and reconstruction of audio only or audiovisual narratives. They reported that children could remember both actions and dialogues better in the audiovisual presentation (see also Calvert, Watson, Brinkley & Penny, 1990; Kozma, 1991).

In Hanson's (1989) review of video and audio research for television, he suggested that TV producers determine if the information to be learned is verbal or visual. If verbal, they are to use redundant audio and video. Otherwise, he suggested that simple non-redundant audio could be used to encourage attention to the video channel.

Monetary and developmental constraints may discourage an extensive use of video and audio in computer software at this time. Computer programs may continue to consist mainly of textual and graphic material. Yet research seems to indicate that multichannel presentations enhance learning (Calvert et al., 1990; Grimes, 1990; Hanson, 1989; Hartman, 1961a; Kozma, 1991). Even though we seem to have a preference from birth for the visual, we cannot over-emphasize one sense at the expense of the other. For too long there has been an emphasis on the visual, accepting as true only what is seen. This is exemplified in our sayings "Seeing is believing" and "Accept only half of what you see and nothing of what you hear." These directly contradict the educational emphasis on oral communication as well as the experience of today's children who have grown up in a video culture with a strong oral communicative component.

A further importance of auditory stimuli is to relieve visual complexity. There is sensory overload when too much information is being presented to the senses (Fleming, 1980; Grimes, 1990; Hanson, 1989; Waterworth, 1984). Although the total amount of information received through the various senses must remain constant, presenting some of the information through the auditory channel may permit a simpler visual stimulus (Baecker & Buxton, 1987).

Although auditory information can replace some visual information, care must be taken in presenting information in the appropriate mode. As sound is omni-directional, it can be intrusive. It is single-channeled, both in the sense that we can comprehend only one message at a time and in the sense that we cannot talk and listen at the same time. Sound is transient and unless provision is make for replaying oral transmissions, they cannot be easily recalled. Speech is serial and time-expending so that messages must be received in a pre-arranged order and at an other-determined speed. Rapid browsing of speech is not usually available.

In their study of the use of sound in flight training simulations, Baecker and Buxton (1987) suggested that auditory presentations be used with simple, short messages that need not be referred to later. They stated that messages should deal with events in time or events that require immediate action. Messages were especially useful if the visual system of the person was overburdened or the environment was too bright or too dark (p. 397).

Sound in Computer Use

Baecker and Buxton (1987) were referring to sound used in adult training simulations that relied heavily on visual presentation. On the other hand, children may use many different types of computer programs in a school situation: drill-and-practice, tutorials, simulations, games, exploratory micro-worlds, or generic tool applications. Furthermore, children do not have the experience and the sophisticated learning strategies of adults. Therefore, Baecker and Buxton's sound criteria cannot be applied directly to children's programs. Sound should be used carefully according to the previously stated properties but its use must be determined also by the educational purposes previously listed.

Why should the computer use sound? First of all, while all other educational media present information to the student, only the computer has a memory so that it can "learn" in order to interact with the student in a meaningful way. The computer can be responsive to the student's actions and become a partner in the learning, as previously only the teacher could. Secondly, only the computer can take on the qualities of the other media. The computer can present video clips and slide and tape presentations as well as provide activities for the student to do.

Thus if the computer is to take on a partnership role in learning, it must not be a mute partner. Just as the teacher relies heavily on oral communication, the computer must have as many channels available for communication as possible. While up to now the computer has relied heavily on the visual channel for presenting information, technological developments are providing the possibility for a greater use of the auditory channel. I will examine the ways sound can be used in the computer and how current developments are increasing its sound capability.

The two ways that sound is used on the computer are for non-speech audio and for speech. Both are useful for communicating some information. Speech communicates information directly through words; non-speech, indirectly by sounds if they are given an arbitrary meaning or directly by those that indicate an occurrence. Of the ways that speech can be used, Waterworth (1984) further categorized it into goal-relevant information and dialogue control information. Although he was discussing human-computer dialogue in which the computer can both speak and receive voice input, this distinction is useful to separate types of communication that the computer can use. Goal-relevant information includes directions, advice, feedback and explanations while dialogue control information includes error signals and extra guidance.

Auditory Displays

Non-speech use, often called auditory displays (Simpson, McCauley, Roland, Ruth & Williges, 1985), can be as simple as warning beeps or as complex as musical themes to represent visual information for blind people. Non-speech auditory displays are often used to give feedback. Picture the expert video-game player who has just had the audio portion of the program cut off. His score immediately goes down for he relies on the non-verbal information to cue him to attend to unperceived dangers.

Gaver (1986) worked at developing "auditory icons" to present direct information about the world to the listener. An example he gave of an auditory icon was the crackle of paper to represent a text file being received by a messaging system or a metal clang to represent a compiled program being received. If the sound came from the left and was slightly muffled, it must have been coming from a window on the left side of the screen and behind the currently opened one. In short, Gaver saw auditory icons as "caricatures of naturally occurring sounds such as bumps, scrapes, or even files hitting mailboxes." (Gaver, 1986, p. 169). They presented information about the world by concentrating on dimensions of the sound's source such as type of sound and direction. Thus it was the sound itself that provided the information rather than a synthetically defined mapping of sounds to concepts. This would be the case in different pitched musical tones used to represent menu choices. The auditory icons in Gaver's sense have a meaning in the real world that can be adapted to the computer.

Digitized and Synthesized Speech

The second use of sound with computers is that of speech messages. There are two methods of using speech messages: digitized speech and synthesized speech. Digitized speech is recorded into a digital form (i.e., computer-readable) which can then be stored in the computer. Synthesized speech is generated following programmed rules. I will examine each type of speech and the difficulties of using each one.

For the following explanations of digitized and synthesized speech, I am indebted to Edwards' (1991) *Speech Synthesis: Technology for Disabled People.* It is a very readable book that explains both digitized and synthesized speech.

Sound can be represented as a waveform and expressed graphically as a curve similar to a sine or cosine curve. The repetition of the curve, measured from one peak to the next peak, represents the frequency or pitch of the sound while the height of the curve, measured from the midpoint of the curve to the highest point, represents the amplitude or loudness of the sound. Figure 2 represents 16 cycles of a generated tone at 22 kHz while Figure 3 represents the sound "aaaaaah" as in "awful". Note the smoothness of a single tone compared to the sound wave of a human voice with its mixture of overtones.

Figure 2. Waveform of a tone generated by the computer

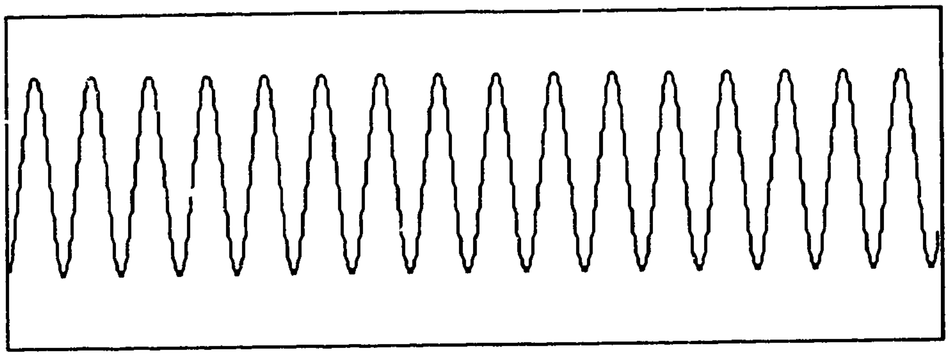
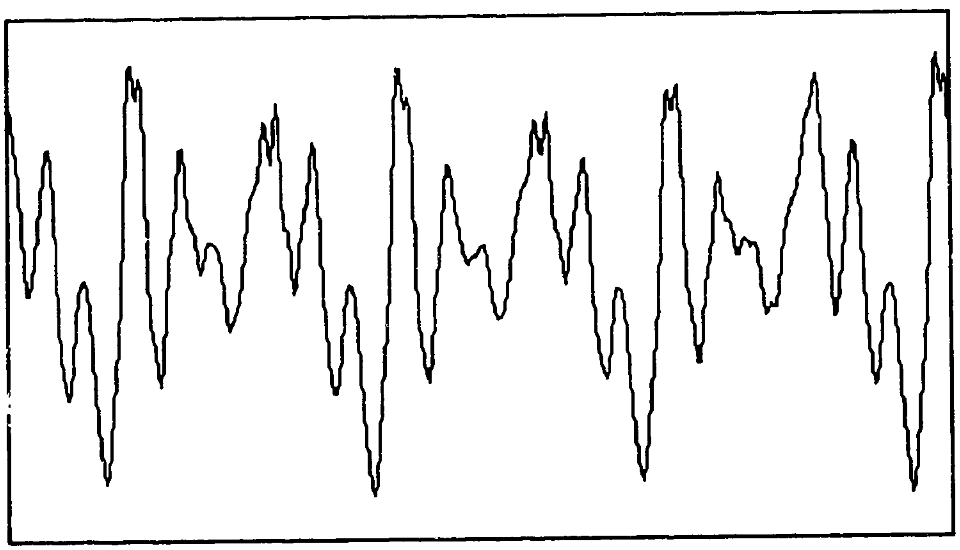


Figure 3. Waveform of "aaaaaah"



To digitize speech, the waveform of the sound is sampled at discrete intervals. The amplitude of the wave is measured at each interval and represented by the nearest number in the unit of quantization. For example, if the amplitudes of one cycle were measured as [8.4, 8.1, 6.3, 5.4, 4.5, 5.2, 6.1, 7.0, 7.9] these would be represented in whole numbers as [8, 8, 6, 5, 5, 5, 6, 7, 8]. The smaller the unit of quantization was, the smaller was the distortion.

Another distortion of sound may be introduced by the assumption that the shape of the waveform between the samples has a constant shape. These errors can be reduced by shorter sampling intervals. Further distortion, called "aliasing," is introduced if the sampling frequency is too short. This distortion can be reduced if the sampling frequency is slightly above twice the waveform's highest frequency. Thus, if the sound frequency is 5 kHz, the sampling frequency should be 1 i kHz.

The difficulty with the use of digitized speech has been its heavy storage requirements. The direct digitization of sound just explained is referred to as "pulse code modulation" or PCM. At a sampling frequency of 6.8 kHz, it would take 10 K of computer memory to store each second of speech. Yet this sampling frequency does not give the best quality. Computer digitizing programs, such as Authorware Professional's **SoundWave**™, offer digitizing sample rates of 5.5, 7.5, 11 and 22 kHz. A second of speech at 22 kHz would take about 32K of computer memory. This is approximately equivalent to the storage required for 5 pages of single-spaced text.

In order to diminish the heavy storage requirement, various data-compression techniques have been developed in which the computer's computational ability has been utilized for data reduction. "Delta modulation" stores the difference between successive samples rather than their absolute values. Decoding is then done by adding the difference to a running total. As the numbers to be encoded are smaller, they take less storage space. A further technique, "adaptive pulse coded modulation" (APCM), stores only the changes in the slope of the waveform. An upward slope would be represented by a 1 and a downward slope as a 0. These techniques are able to halve the storage requirements of PCM.

Better compression can be achieved with "linear predictive coding" (LPC). This assumes that there is repetition in the waveform as in the example in Figure 2, and earlier parts of the waveform are used to predict later ones. Thus, some repetitions can be omitted. Techniques based on this coding can lower the storage requirement of the same speech to about one-sixth of the original.

The advantage of digitized speech is that it can sound natural. Some computerized telephone systems use concatenated digitized speech or the combining of small clips of digitized words. The University of Alberta's student registration system has a standard welcome in natural sounding digitized speech. Then, once the student number is input, it responds with "Your last name begins with L-A-M-Y." The first part of the response sounds natural and is a phrase in its dictionary. The four letters are strung by the computer in real-time, that is, as it is speaking. The last part of the sentence sounds unnatural but is understandable.

On the other hand, synthesized speech is completely computer generated. As a sentence or message does not have to be predetermined, the need for storage space is minimizea. However, other difficulties are encountered.

A synthesizer must begin at the level of phonemes, the smallest segments of sound in a language, and combines them to make the words it needs. However, a combination of two or more phonemes can immediately cause problems because one phoneme can affect the pronunciation of the second. This effect, called "coarticulation", cannot be simulated in synthetic speech. To deal with this problem, high-quality speech synthesizers create a list of allophones, variations of the basic phonemes.

Another problem for synthesizer developers is to create natural sounding speech sounds. People use not only their vocal cords in speaking but also the lips, the teeth, the tongue, the palate and the oral and nasal cavities. Furthermore, even though there are only five vowels in English, there are about 16 vowel sounds, not including the double sounds, or glides, for vowels that alter from one sound to another as they are pronounced. As well, aspirants, in which the vocal cords are held together but not vibrated, and fricatives, in which constrictions are formed by the lips and teeth, tongue tip and teeth, the hard ridge behind the front teeth or the tongue further back along the palate, add more sounds for the developer's dictionary. All these are added to the list and rules are created for their use.

Even though less storage is needed than for a collection of digitized sentences, a synthesizer must have storage for its dictionary of phonemes, allophones, and glided vowel sounds as well as a list of words that form exceptions, such as the sound of "gh". Depending on the word, (e.g., tough and though), this phoneme may have different sounds. Furthermore, there are words, such as invalid, that are said differently depending on the context. It is no wonder that, with all these development difficulties, an inexpensive synthesizer can be difficult to understand.

Added to this is the problem of prosody that includes stress, rhythm, timing and intonation. Since the meaning of a sentence such as "This is my son" can be completely altered by variations in prosody, a computer would require understanding of the sentence as well as understanding of the person's emotional state to convey an intended meaning using prosody. Prosodic features are very important in natural speech and can be used "to convey intention, emotion, interpretation, elaboration, and even negation of the surface meaning" (Waterworth, 1984, p. 226). The effective use of prosody may be beyond the capability of a synthesizer.

With the increased availability of massive storage, compact discs with over 600 megabytes of storage or 75 minutes of high quality audio (Reynolds & Anderson, 1992), hard drives in the 1000 megabyte (1 gigabyte) range, and 3.5 inch optical disks with 125 megabytes (Myslewski, 1992), the problem of digitized sound storage is no longer prohibitively expensive. By the time research can be done with digitized sound, schools may have the storage capacity needed to store large lessons.

The importance of sound and how it can be used in computers has been reviewed. The important question that now remains is how to use speech in educational computing. I will first investigate how sound can be used in relation to the diverse educational uses of computers. Then I will focus on speech in the educational use that students make of computers. Finally I will offer some suggestions for a creative use of speech by students.

Sound in Educational Computing

Computers can be used in three main ways in education: programming, administration and computer-based learning (CBL). I am using the latter term as defined by Reynolds and Anderson (1992). Their definition of CBL included computer-assisted instruction (CAI), computer managed instruction (CMI), and computer supported learning resources (CSLR). CMI included computerized testing, computer-assisted learning performance reports and any other computer supported way teachers may keep track of student achievement. CSLR provided access to any information that was needed for learning and included databases, telecommunications and hypermedia.

For a long time, computer-assisted instruction (CAI) was connected to a behaviorist orientation to learning. A better term now being used is computer-assisted learning (CAL) which focuses on the learner as an active agent in the educational enterprise. CAL is generally understood in a restrictive sense to mean a range of drill-and-practice, tutorial, simulation, and game programs. These tools, placed at the students' disposition, are used to attain their objectives and goals. By the use of the term CBL, I wish to include any use of the computer by the student for an educational purpose whether it is the use of an instructional program or a non-directive application tool.

Sound in Programming and Administrative Use

It is possible for students to generate music in programming with LOGO, but not speech at this time. Voice navigation for controlling computers is coming but, although it will undoubtedly benefit the learning of students who have physical handicaps, the investigation of students' speech input is beyond the scope of this study.

Since speech in the administrative uses of computers does not directly affect students' learning with computers at this time, we are left with structured lessons in CBL and programs for student-directed computer use. I will investigate each one in turn with descriptions of present and possible future research.

Sound in Structured Lessons

Since speech, like text and graphics, must be integrated into a well-structured learning unit, it must be dependent on the lesson content and on the needs and abilities of the children who are using the computer. This means that the use of speech must be studied within specific topics and lesson styles and for particular age groups. For example, a sight word practice program for kindergarten children may include spoken commands and redundant information presentations through diverse symbol systems, with verbal information being displayed graphically, textually and aurally (Olson, Foltz & Wise, 1986; Olson & Wise, 1987; Reitsma, 1988). A science tutorial for grade five children may include spoken commands, appropriate sound effects and complementary information presentations.

Even though the specific use of sound may change from one program to another, it is possible to list different ways sound has already been used in research studies. However, in most cases, the main focus of the inquiry was not the use of sound itself.

Research Using Synthesized Speech

Nicolson, Pickering and Fawcett (1991) used a multimedia environment to give spelling support for dyslexic children. A parent or teacher would read an interesting passage for a child to write. The parent or teacher would then type the child's version of the passage and create a bug card for each error. Finally the child corrected all the bugs in the passage.

The researchers used synthesized speech to supplement the text displays. If the child held the mouse pointer over a button, the program would say its name. If the child selected some words, the words would be read by the computer if the speak button was then clicked.

Redundant speech was used in this study to support students who had weak textual reading skills. The choice of synthesized speech rather than digitized speech reflected the philosophy of the researchers in that they wished to give the parent or teacher the opportunity of choosing passages for a particular child. The invariant names of the buttons could be stored as digitized speech but the reading of parent or teacher-chosen text required the use of synthesized speech.

Although Ford and Cameron (1986) did not use a computer in their research, their study is of interest for this paper as they examined the use of speech in both information presentation and student response. The presentation conditions consisted in oral or oral-plus-written information; the response conditions allowed a pointing or a verbal response.

They found that grade one students could recognize insufficient information better in the oral-plus-written presentation condition and in the verbal response condition.

The researchers used speech both for presenting information to the students and for expressing their knowledge. The results indicated that more in-depth cognitive functioning could be enabled by dual sensory processing in the orally supported text and by the processing of two symbol systems to give an oral response about a graphic image.

A study with similar aspects was that of Torgesen, Waters, Cohen and Torgesen (1988). They used a computer program to present word sets to grade one, two and three students. Word sets were presented as graphic representations of common words, graphic representations with synthesized speech and as synthesized speech alone. In the first two conditions, students first learned the graphic representation of each word before having to choose the correct word from a set of two or three words. In the audio component of the second and third conditions, students heard the word and its use in a sentence. The researchers reported that all three conditions were equally effective in teaching accurate reading although the students preferred the visual and visual-auditory to the auditory-only. In this study, speech was used to supplement the graphic images when it was present or to carry the whole cognitive load when the graphic images were not present. It is noteworthy that the students preferred the combination of the graphic and verbal symbol systems. Although there was only one symbol system being used in the auditory-only condition, it was less appealing to students at this developmental level; graphic images were more concrete than a spoken sentence.

Calvert, Watson, Brinkley and Penny (1990) also studied the improvement in young children's ability to recall words when either two symbol systems or two sensory channels are used. In their study, kindergarten to grade two children were shown words presented with and without action and words presented with and without verbal labels. Actions were appropriate movements for the particular word (i.e., a frog would hop). For the verbal labels, the computer spoke the name of the object in synthesized speech. The researchers report that the addition of the action and verbal labels increased recall among the poor readers among the older children to the same level as the better readers and labels increased recall among all the kindergarten children. Although speech and action were both used in this study to complement graphic images, the purpose of their introduction was to observe their possible effect on recall. It was found that they enhanced recall but it may be assumed that they first enhanced content comprehension by means of both dual symbol and multi-sensory processing.

Conners and Detterman (1987) used sound and synthesized speech in their study of the information processing involved in word learning by mentally retarded students ranging from 9 to 22 years old. The computer said the word on the screen in the learning mode, said the word to be picked out of four in the question mode and gave verbal feedback when correct, for example, "good," "yes," or "right." In one of the cognitive tasks, the computer said the instructions and generated tones for feedback. In this study, sound was used for instruction, redundancy of verbal input, questioning and feedback.

Research Using Digitized Speech

Although Jaspers and Ji-Ping (1990) did not describe results of a research study using speech, they offered an alternative system for providing inexpensive audio support to CAL and suggestions for its use. They developed a computer-controlled tape recorder for finding audio clips corresponding to visual displays on the computer screen. In their article, "Interactive audio for computer assisted learning," they described the Interface Control Board used to control searches for appropriate audio clips by the tape recorder, the software they developed, and suggestions for its use, including providing audio selections for words, sentences or long explanations in second-language learning or complementing graphic images by providing spoken comments or explanations. Concerning research questions about the use of audio information in computer lessons, they indicated that researchers could examine questions "of redundancy of visual and auditive information, of memorizability of audio messages, of codability, of adaptation of the audio component to the target group, and other design aspects" (Jaspers & Ji-Ping, 1990, p. 73).

Kincaid, Mullully and Kincaid (1992) produced demonstration programs incorporating the use of digitized speech for second language learning. In their programs, digitized speech was used for pronouncing words, phrases or short sentences. In the learning mode of one program, a graphic image was shown while its name and a short sentence about it were said. In another program, dialogues were taught by having phrases and short sentences spoken. Since students could record their speech, they could compare the native speaker's pronunciation to their own in instant feedback.

Using **HyperCard**, Davidson, Coles, Noyes and Terrell (1991) studied students' learning of reading by creating a multimedia book on the screen. Students could ask the computer to read the page or single words on the page. Students could control when they wished to go to the next page, or even to return to a previous one. Their book was a simplified version of the Discis books released in May 1990. Although the students who followed the computer program achieved slightly higher results in word recognition after four weeks of daily computer use, this result could be attributed to other factors. The interesting aspect of this study was that a twelve-year-old girl's voice was used.

Bridgman (1990) reported a pilot project to investigate audio design in a computer-based training program, **Microtext talking tutor** for adults. His use of digitized speech consisted of voice error-messaging, prompting after repeated errors to give extra information and/or encouragement and, after three tries, the insertion of a correct response with a voice confirmation of the actions taken. His rationale for these uses was that the visual complexity of the screen may cause students to miss an error message. The criteria he used for integrating voice were:

(1) Introductory and/or background material may be presented using an audio rather than a textual medium up to a maximum of a 30 second message, with 10–15 seconds being the preferred duration.

(2) For learning material, the audio cue should be limited to 5–7 seconds.

(3) For learning material, each audio cue should only contain one piece of learning material.

(4) For learning material, between each audio cue, a visual cue of preferably a graphical nature (but textual where appropriate) should be presented to reinforce the audio cue (p. 177).

He also noted that voice error-messaging was not always well received, especially in a group environment, when it could become embarrassing and de-motivating. Speech was used in this tutorial for direction and feedback and was especially useful to draw attention to messages that may be missed within a visually complex display. Although this study was used for adult training, the criteria presented above for integration of audio are interesting. However, they cannot be generalized to use with young children. Experimental research is needed to generate criteria for integration of audio useful for diverse age groups.

In conclusion, the following list summarizes the ways that sound or speech have been used in the research studies examined:

(1) to provide support for the textual representation of a word (or words),

(2) to provide an alternative symbol system for a graphic image of an object by naming it,

(3) to provide comments or explanations about a graphic image,

(4) to give simple directions,

(5) to give feedback on actions taken by the computer,

(6) to give feedback on wrong or correct choices made,

(6) to provide more information if errors are repeated,

(7) to offer a pronunciation of a second language word (or words), and

(8) to allow voice input for comparison to pronunciation by a native speaker.

As well, non-verbal audio cues can be used to represent natural sounds occurring in nature, i.e., the unique sounds of animals, gushing water, or doors opening, so that the computer environment may contain audio cues familiar to children in their world.

Research is now needed to study the different uses of speech in a variety of simple CAL programs for young children so that a beginning criterion for integration of audio cues can be generated. This study must include different age levels, the various ways of using speech and the children's observed responses to, and preferences for, differing lengths and complexity of audio cues.

Sound in CAI/CAL Commercial Programs

This observation of student responses to sound need not be limited to only customized CAL programs. Sound may also be studied in commercial CAL programs including drill-and-practice programs. These programs still have a place in educational computing, providing they are a means to achieving educational objectives. One objective that drill-and-practice programs can promote is skill development. For example, some beginning readers may need practice in auditory discrimination of the beginning, middle and ending word sounds. A good computer program may make that drill more pleasurable by a judicious use of sound, color and animation.

Daisy's Quest, a program developed in 1992 by Great Wave Software, does this while incorporating most of the uses of sound mentioned in the list above. Because of its intended audience of beginning readers, **Daisy's Quest** relies heavily on speech, using it for directions, tutorial explanations, feedback, and graphics support. Other uses of sound included in the program are sound effects and music.

This lesson is presented in an adventure format in which children are asked to find the dragon, Daisy. To personalize the adventure, students pick one hero out of eight whose name is added to the beginning of any directions. In order to minimize storage requirements, the Wizard concatenates speech fragments into sentences. This is quite evident in the pause in directions for traveling about the scene in which the Wizard says: "Back to the..." and "dell", "cave", "forest" or "cottage."

At the beginning of the lesson, students are given oral directions and the Wizard continues to give optional directions throughout the lesson. In a tutorial section, the Wizard explains that part of the lesson while presenting sample questions. In the drill section, there are two types of questions presented orally; true and false and multiple choice. Spoken feedback is given for all choices and students must answer five questions correctly to gain a point towards finding Daisy's hiding place.

To help students answer questions and navigate, there is auditory support for all graphics and navigation icons. This occurs even when students are choosing the correct matching picture, thus providing auditory reinforcement of the desired sound. Sound effects provide a sense of reality, for example, an echo in the mining cavern and the ship's captain welcoming the adventurer to his cabin. A short musical interlude occurs each time the student finishes a set of questions and could become intrusive but using the navigation icons cuts off the music.

Adults may find the program's pace slow although they can bypass the Wizard's explanations. Young children, especially those requiring practice in auditory discrimination, appear to enjoy the program and have benefited from it.

Sound in Student-Directed Computer Uses

There are many other CBL applications already on the market that incorporate the use of sound. These can be used to investigate children's responses and preferences as well. The following are samples of various types of applications and their use of sound.

Sound in Exploration Programs

Starting at the kindergarten level, there are two excellent applications by Broderbund that promote exploration: **The Playroom** and **Just Grandma and Me**. **The Playroom** appears in both black and white or color versions. **Just Grandma and Me** requires a Macintosh with a color monitor and a CD-ROM drive.

The Playroom. Once the program is started, the child works in a central room, called the playroom. Other screens, representing other rooms, may appear by the selection of a specific object. For example, a child may click on the mouse hole and be presented with a game activity.

A child may click on any object to see and hear a response. For example, clicking on the radio causes music to be heard. If the child clicks on the poster, the little girl nods her head and the computer says "yes." The corner may be clicked to go to another poster with a similar word, action, and digitized speech.

Clicking on some objects, the child may be taken into an activity. For example, clicking on the clock permits the child to play with time. Hours can be changed, the computer says the time and day and night activities for that time are presented. Other activities include typing three or four letter words on the computer, playing a number game alone or with a partner in which the computer reads the number, counting objects, constructing wacky animals by clicking on parts, or manipulating labeled objects in a scene.

Sound in **The Playroom** includes digitized speech for time, words or numbers shown on the screen, and non-verbal cues such as winter wind or music. While the program's use of speech enables children to match verbal knowledge to text and number symbol representations, the use of sound provides a microworld that incorporates many of the sounds that a child would hear in the real world.

Just Grandma and Me. Another program that presents a preprimary or primary level child with a microworld is Broderbund's **Just Grandma and Me** (see Figure 4, created using the Just Grandma and Me, copyright 1992, Broderbund Software). One of their **Living Books**, it is a computerized version of a book by Mercer Mayer.

This program permits the child to choose between having the whole story read or playing with the pictures. Each of the twelve pictures is a scene that includes a sentence read by the computer and animation. When the scene opens, the main characters carry out the actions described in the sentence. If the child has chosen the PLAY mode, many objects will come to life and repeat their actions and words whenever the child clicks on them. Imaginatively designed, the unexpected effects are such as to appeal to the preschool child. Beach umbrellas take off as rockets, star fish dance, ants march out of a sand castle, and clouds change shape into tugboats or ice cream sundaes.

Both verbal and non-verbal audio cues are clear and understandable. Although speech requires a large storage capacity, the CD-ROM disc can provide sufficient storage to display text and present speech in English, Spanish or Japanese. Like **The Playroom**, the use of sounds from nature provides greater realism in this microworld. The sound of sea-gulls and ocean waves add realistic details to the ocean environment.

The Discis books. Exploratory reading programs for grade one and two children include the Discis books. In these computerized books, the child can explore text, meanings and pictures. The entire book can be read in clear, digitized speech or the child can ask for the reading of sentence, a word, the meaning of a word or word phrase.

Figure 4. Scene from **Just Grandma and Me**, copyright 1992, Broderbund Software

Figure 5. Page of **Paper Bag Princess**, copyright 1990, Discis Knowl. Research Inc.

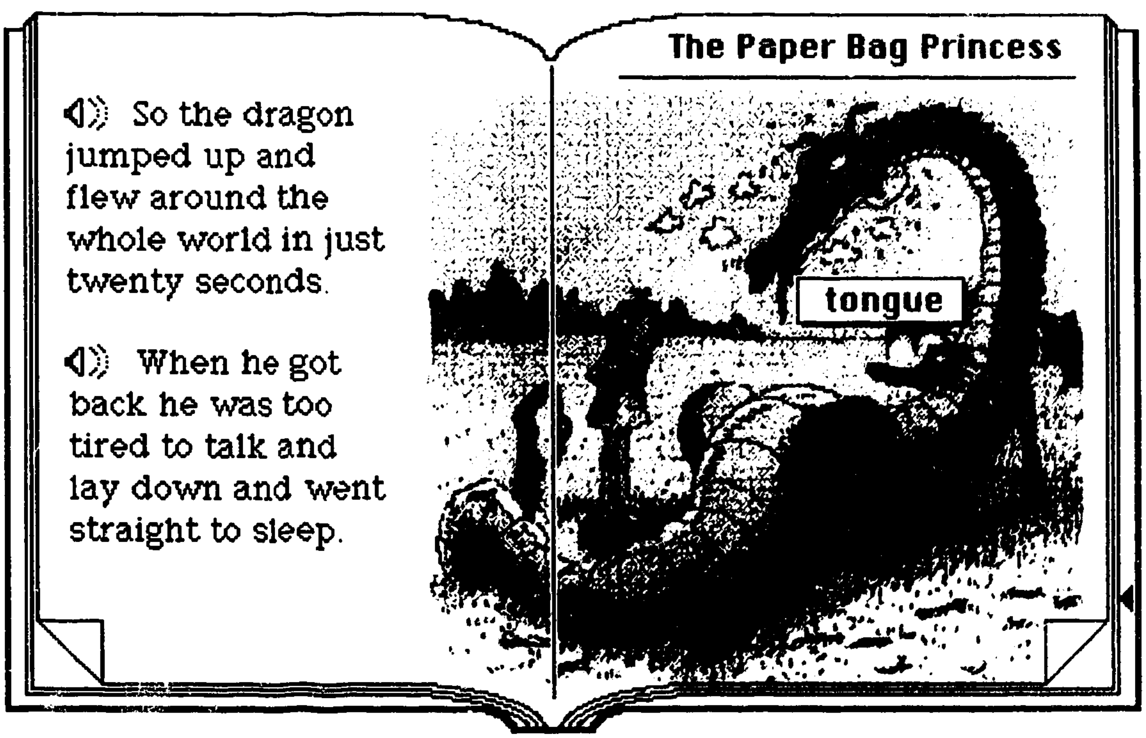


Figure 5 shows a reduced example of a full-sized screen from the Discis book, **The Paper Bag Princess** by Robert Munsch. In this example, the dragon's tongue has been clicked. The computer says "tongue" and shows the corresponding word. While this permits children to explore the pictures, the visual label and the spoken word offer dual-channel processing as well as the use of two symbol systems to enable greater comprehension.

Spelunx and the Caves of Dr Seudo. An exploratory program useful for grade 5 students is Broderbund's **Spelunx and the Caves of Dr Seudo**. In this program, a microworld is created for students to explore.

Three caves or rooms present multiple activities for students to explore art, music and scientific concepts. In one activity, the student controls the temperature and feeds a lizard by dropping pellets into a bowl. Since the temperature controls the lizard's metabolism, too low a temperature causes the lizard to continue sleeping and a worm emerges from the sand to eat the food.

The main use of sound in this program is non-verbal sounds representing natural world events, such as a door creaking, thunder in the lightning machine, and musical chords in the music machine. The only two instances of speech cues were in reading a sentence of student ordered words and a welcome by Dr Seudo to the cave. The speech quality was poor; the sentence reading was disjointed and the welcoming speech was difficult to understand.

Most of the sound in each of these programs, except for the Discis books, has been non-verbal audio cues to help in the creation of an exploratory microworld. Only in **Just Grandma and Me** and the Discis books has the speech quality been superior. While the Discis books have focused mainly on using speech as text support and for reading comprehension, **Just Grandma and Me** has used sound in diverse ways, for feedback, directions, entertainment, and textual support.

Sound in Research Tools

Students may use computerized databases for research. Examples of databases that contain audio clips are **Multimedia Birds of America** and the **Grolier Electronic Encyclopedia**.

Multimedia Birds of America. This CD-ROM disc contains textual information and pictures of native birds of North America. Although the pictures are colored, they may be displayed on any Macintosh.

As the textual information has been taken from the 1840 first edition of Audubon's *Birds of America*, it is more suited to adults in both content and writing style. However, there are many excellent quality audio clips of selected birds.

__**Grolier Electronic Encyclopedia**__. This CD-ROM disc contains textual information and pictures on many topics. One interesting sound feature is the inclusion of audio clips of famous people's speeches, including Martin Luther King Jr.'s "I Have a Dream." This permits children to hear meaningful moments of the past. With these types of databases, students can search for information but they can also create multimedia presentations on a topic of their own choice, a presentation that incorporates graphics, text and sound.

Sound in Productivity Tools

The term "productivity tools" describes those programs that enable or enhance students' creativity. These include word processing and graphics applications. Student use of these applications can lead to a more complete integration of computers into learning activities, since children often request the use of technology for their assignments (Anderson, Oppenheimer & Fullan, 1992). There are interesting productivity tools for various age levels that contain sound effects or speech.

__**KidPix**__. Broderbund's **KidPix** is a graphics program for children in primary grades. The graphics tools can create bizarre effects so that young children can enjoy playing with the program as they learn. Speech in **KidPix** includes the use of both Spanish and English talking alphabet letters and numbers. Optional sound effects are connected to the graphics tools.

KidPix allows for a creative use of speech by allowing students to record their own voices to attach comments or poetry to a picture. This option requires a Macintosh model with a microphone (a Classic II, Macintosh LC or higher) or else a computer peripheral for recording and digitizing sound.

__**Once Upon a Time**__. Another example of a combination graphics program and word processing program is Compu-Teach's **Once Upon a Time**. This program provides a selection of several background scenes to be used by a child in creating a book. Pages can be either graphics or full text pages.

Graphics pages contain a background and objects chosen by the child. Objects can be moved to any position, shrunken or expanded and flipped to face either direction. Four lines at the bottom of a graphics page can be used for text entry.

The speech in **Once Upon a Time** is used for oral support of object names. A student may click on words to have them read. If an object is chosen by typing its name, that name is automatically read again.

Creative Uses for Sound

With the microphones that come with many Macintosh computers, students can now digitize their own voices or other sounds. This, coupled with programs such as **KidPix** or **HyperCard**, can permit students to create multimedia presentations using graphics, text and sound. An elementary student can draw a picture in **KidPix**, use alphabet letters to write a little poem, and record a short comment or read the poem. An older student may create a **HyperCard** stack with textual information, graphics, video clips and digitized sound that illustrate a concept, and personal recorded comments.

One creative use of sound witnessed is that of **HyperPostCards** developed by Dr. Gerri Sinclair, Simon Fraser University, in 1989. Elementary school students of a school in England and in Japan created **HyperCard** stacks to send to the other school. Stacks dealt with English and Japanese labels and digitized sound for pictures of common objects, questions and responses to each other, and city and school descriptions with text, digitized sound and digitized pictures.

Although the addition of speech greatly increased the size of the stacks, speech can add so much to a stack's appeal and can disclose something about the speaker. The attempts by the English students to pronounce the Japanese words showed their desire to communicate with their peers in another part of the world, while hearing the voices attached to each student's picture gave a greater knowledge of that person.

Research Directions

With the possibility of cheaper massive storage devices, the integration of digitized sound into computer-based learning is now feasible. However, very little research has been done in effective and appealing use of speech in educational computing. Much of the elementary educational research that has incorporated sound has focused on other learning aspects. Research that has examined the use of sound for human-computer interface and that has sought to develop criteria for effective use of audio has been directed to adult learning.

What is needed now is

(1) to incorporate varying uses of sound in many kinds of CBL, observing student interest and acceptance,

(2) to vary differing aspects of sound, to begin developing research-based criteria for effective uses of sound, and

(3) to work with different age levels so that the influence of age and development variables on children's interest and ability to accept and to learn with sound can be observed.

This must be done so that feasible criteria and tentative conclusions of how sound may be effectively used in CBL can be created. It will also offer future research a starting point for deepening, expansion, or challenge. Thus, the questions, after conducting the literature and computer software research, were:

1. Given the present possibility of computer technology to present digitized natural-sounding speech, what kinds of auditory presentations in computer-based learning are appealing to children in grades two and five?
2. Given control, will students make choices or keep the default settings?
3. Given increasing opportunities for control, will students grow in the ability to make choices that reflect their preferences?
4. Given an opportunity to evaluate computerized lessons, can students give useful suggestions for their revisions and the design of future lessons?
5. What effects will there be in the collaboration of practicing teachers and a computer software designer to create computer lessons integrated into various areas of the school curriculum?
6. What effects will there be in the collaboration of students and a computer software designer to evaluate computer lessons experienced by the former?

Given the complexity of the relationship between the questions and my desire to give children control of their actions within the cognitive learning theory, a naturalistic mode of inquiry was indicated. The next chapter will describe the research methodology used.

CHAPTER 3

RESEARCH METHODOLOGY

Marshall and Rossman (1989) suggested that qualitative study be used for various types of research including "research that delves in depth into complexities and processes, ... research for which relevant variables have yet to be identified, ... research on ... innovative systems" (p. 45). A qualitative study may provide a thick description of a phenomenon being explored, showing the complexities of variables and interactions embedded in the data observed within the natural context. A qualitative study may be used to investigate new phenomena in order to inductively generate tentative questions for further research.

This study was investigating a complex experience. Using computers and being presented with text, graphics and sound in computer use are experiences that may not have the same meaning for each participant in the study (Salomon & Gardner, 1986). Since this study sought to explore a phenomenon from the point of view of the children, a qualitative study was needed. It allowed for a detailed description of the situations, people, interactions and observed behaviors as well as in-depth interviewing of the students and teachers.

The choice of a qualitative study flowed from my acceptance of a cognitive theory of learning with an information-processing framework. Although the lessons did not place students in a discovery environment to facilitate construction of personal knowledge, it gave them a limited measure of control in order to experiment with choices provided and so discover their own preferences. Once discovered, these preferences were stated through interviews as well as by analyzing computer data of student performance to interpret apparent preferences. To limit the boundaries somewhat and to ensure that students experienced some auditory presentations, student choices were generally only between having audiovisual components on or off. Menu choices were provided at a later stage in grade 5 but, in these cases, students were asked to choose all parts of the lesson on their first use.

The focus in this exploratory study on auditory presentations was made because there has been research on criteria for the use of graphics and text but, until the development of CD-ROM discs and massive storage devices, the use of sound in computer-based lessons was severely limited. Because of the exploratory nature of this study, data on student choices of auditory presentations were generated by the computer for all the children of the class. The analysis of this data was informative in evaluating the current lesson design and planning variations of auditory use in the following lessons.

It also helped in determining which questions to ask in the student interviews by "supplying background data, getting overlooked information and helping avoid 'elite bias'" (Miles & Huberman, 1994, p. 41). On the other hand, both the answers given in the student interviews and the observations of student computer use deepened my understanding of student-computer interaction. McMillan and Lai (1990) pointed to the need to examine context broader than just that of the activity in question since learning experiences are not confined to a computer experience or a classroom activity. Open-ended questions may extend the contextual boundaries in order to integrate relevant aspects of the use of sound not immediately apparent within the computer experience.

Of the different types of qualitative studies, the case study method was the most appropriate one to use for this investigation. Both J. Johnston (1984) and Rice (1984) encouraged the use of case studies in evaluations of, and for developing baseline data with, new media. Cronbach (1975) differentiated case studies from other studies by the concentration on a single phenomenon to uncover the interaction of significant factors within this phenomenon. Merriam (1991) proposed that an important factor in determining this choice was whether the focus of the investigation was a bounded system. Yin (1989, 23) indicated that case studies are used when "the boundaries between phenomenon and context and not clearly evident; and in which multiple sources of evidence are used." Bromley (1986, p. 23) stated that case studies "get as close to the subject of interest as they possibly can, partly by means of direct observation in natural settings, partly by their access to subjective factors (thoughts, feelings, and desires)." Merriam (1991) pointed out that case studies can be descriptive, interpretive or evaluative. In the latter case, the researcher makes a judgment based on the data.

This study used a descriptive-evaluative type of case study. It aimed to describe and to develop baseline data within a single phenomenon, the choice between text and auditory presentations in computer-based learning. Choices needed to be placed within a broader context of student control. The study was embedded within yet a larger experience, the collaboration of teachers and a computer software designer (the researcher) to develop computer lessons integrated in the school curriculum. Although interviewed students were asked open-ended questions that included relevant aspects interacting with their choices to determine preferences, these aspects were considered mainly in relation to control and the phenomenon of audiovisual preferences (Bogdan & Biklen, 1982). Although observations and questions were focused on student-computer interactions in order to discover these preferences, an important by-product was the collaboration of students and designer in the evaluation of the computer lessons.

To research within the context of student control and critical reflection while maintaining the boundary of audiovisual preferences, six students within the same site were selected to be a reflective group and to provide entrance into the thought processes and preferences of their age group. Because of the collaboration with the teacher and students for lesson design and evaluation and the observation and computer tracking of all the students using the computer lesson, the case unit was the classroom.

Research Design

In order to study this phenomenon effectively and efficiently, many design factors were planned before starting the research. These factors included the selection of site and students, my role in this study, a systematic outline of various aspects of auditory presentations to be used when designing the computer lessons, the research strategies to be used, data collection in type and manner of collecting, data management, data analysis strategies and a research time line.

Site and Student Selection

The site chosen was that of an elementary school containing Macintosh LC computers in a non-laboratory environment. This choice was deliberate because new schools will be purchasing better equipment. As this case study will provide an example of this newer technology in use, the results will have greater applicability to administrators and teachers wishing practical guidance in their use of computers.

The school chosen for this study was a one-year-old school in a new subdivision of Edmonton. Containing double or triple classrooms for each of the grades from K to 6, it was a spacious, one-story building with the main corridors forming a "Y". It had been operating only one year and has an air of newness, cleanliness and light. Student work displays, an aquarium, display cases and large bulletin boards with thematic displays lined the wide halls. The school contained a music room that could be transformed into a stage opening out to the foyer at the bottom part of the "Y". At another entrance to the foyer was the gym. The library, also very bright and spacious, had a large arched entrance at the center of the two branches of the "Y". Classrooms lay along the sides of the "Y", at the tip of the two branches and in portables at the end of a corridor.

Classrooms had a large board at the front of the room, shelving under windows along one side, cupboards with counter space along the other side, and either full cupboards at the back or low cupboards if there were more windows. Bulletin boards were situated on each side of the windows and the front whiteboard. Many of the classrooms had stand-along bookracks. Along one side of each classroom was an alcove with a table and several chairs. Each classroom also had a sink.

In order to provide greater access to the 30 Macintosh LC II computers with color monitors, they were not situated in a one-room lab setup but rather one computer was placed in each of 14 classrooms for teacher and student use and the remaining 16 were placed in the two corridors on each side of the library. Students from nearby classrooms could access these computers when the machines were unoccupied. Except for one dedicated to CD-ROM use at the library entrance, all Macintosh computers were networked. Students using the Macintosh computers were seated facing the wall. Six computers were located along one wall on the left side of the library while nine more were situated along both sides of the corridor on the right side of the library.

To allow for sustained use of computers for word-processing, the school had also purchased three class sets of the Brother Wp-2 laptop word processors that could be signed out by whole classes for classroom and home use. Students typed their work at their own pace and then printed their work at three dedicated printers in the hall. This effectively freed the Macintosh computers for more varied use with several programs on the network: **KidWorks 2™**, **KidPix™**, **ClarisWorks™**, **HyperCard™**, **Math Blaster™**, a **Living Books™** CD-ROM, and the **Grolier's Encyclopedia** CD-ROM. One Macintosh computer was dedicated to graphics work with special graphics software, a color scanner and a color printer.

Three students in grade 2 and three students in grade 5 were chosen by the teachers. Requirements in choosing the students were:

a) at least one of each gender,

b) varied ability levels in both learning and computer use,

c) high ability of articulation, and

d) good hearing, as tested by an audiometric assessment.

The hearing requirement was important to prevent erroneous conclusions arising because of a physical lack. The six students had an audiometric assessment done during the course of the research.

The grades chosen and the criteria established permitted the observation of variations in visual or auditory preferences because of different abilities, reading levels or developmental stages and provided a contrast between students. With such a range of students and breadth of lesson content, the research had to include rich descriptions of student observations, student interviews and stated preferences by all students in the class so that any conclusions could be seen arising from the data.

Role of the Researcher

Since the phenomenon to be investigated was actually only one facet of software in computer-based learning, the subject matter, content and learning objectives of the computer-based lessons developed could be determined by the classroom teachers. This entailed the taking on of a collaborative role with the two teachers in the creation of the computer lessons.

Hord (1986) distinguished between collaboration as "the parties involved share responsibility and authority for basic policy decision making" and cooperation as "parties agree to work together" for their separate and autonomous programs (p. 22). Carson and Jacknicke (1989) simplified the definitions. Collaboration, to them, meant to work in conjunction and cooperation meant to work together. Hord also stressed the large time investment in using the collaboration model. The level of collaboration with teachers in a project always depends on their available time and energy.

In this research the teachers and I collaborated in the decision making for the creation of the software lessons. The teachers chose the content and learning objectives while I planned the lesson design, the screen displays, the level of student choice and the balance between text and auditory presentations. During lesson implementation, there was collaboration with the teachers in a planning session to determine how best to free students from class time to use the computers. Afterwards, there was a session with the teachers to report the results and determine whether the lessons should be repeated or a new one prepared. In this way, the teachers collaborated in the research flow and direction.

There was also collaboration with the students. The three interviewees in each class collaborated in lesson design by evaluating each lesson and giving suggestions for its improvement. Their interview responses influenced the revision of the present lesson and the design of future lessons. While the students used the computers, I acted as a computer instructor and helped students with lesson content as well as computer usage. This permitted me to remain in close contact with all the students without being too obtrusive. What they did and said was observed to determine why they made particular choices. As these reactions and computer tracking results, described later, influenced the design of the lessons, the students in the class also had a collaborative role in the software design.

Plan for Auditory Use

My role in this study included designing the computer lessons. Since no one lesson could contain all the possible uses of sound, successive lessons were needed to incorporate new aspects of auditory use and to revise and to refine previously unacceptable or marginally acceptable aspects.

Table 1 shows a sample of the various aspects of auditory presentations originally planned for incorporation into lesson design. This chart became a very important guideline for the development of the lessons during the year. The chart would be examined to see which aspect had not been covered so as to include it in the next lesson.

Table 1. Various aspects of auditory presentations to incorporate into lessons

Aspect	Variation 1	Variation 2	Variation 3
Choice	audio required	audio preferred	audio requested
Speaker	male adult	female adult	child
Frequency - auditory directions	every time	twice when new directions needed	once only when new directions needed
Audiovisual Redundancy	audio and text always given	text occasionally given	no redundancy
Feedback	speech for positive, non-speech audio for negative	speech for both	non-speech audio for both
Hints/suggestions	audio and text	audio only	text only
Preference for use	directions	explanations	hints/suggestions
	positive feedback	negative feedback	text support
Length	0-5 seconds	0-10 seconds	0-15 seconds

This organization was required to present variations and to provide for student choices in these variations. The lessons presented choices in only some aspects to ensure that students always had some auditory experiences. By the last lessons, students were given more control in their choices between visual or auditory presentations and, as well, were given a year-end questionnaire to enrich my information on their experiences and to provide for a different measure of their preferences.

In designing the first lessons, assumptions based on a few predictions of student preferences needed to be recognized. By choosing to go against these assumptions, I tested the value of the preferences. The variation opposed to an expected preference was used to encourage choice. I expected children of both grades to prefer auditory directions either not repeated each time or with student-controlled repetition. Therefore, the first lesson had repeated directions each time.

The research already reviewed indicated that text redundancy is useful, especially for grade 2 students. On the other hand, grade 5 students may prefer related information. Therefore I planned to provide redundant text explanations to grade 5 students and no redundancy to grade 2 students. However, I did not provide redundant text explanations to either grade until towards the end of the year. I also expected that there would be much variation between children because of preferred learning styles but that most children would not make a positive choice for auditory material without having experienced its benefits. In order to test for student preferences, I had to ensure that students received auditory presentations in every lesson. The question of whether students would choose auditory presentations if they had never experienced them will have to remain for another study focusing on this question.

A problem foreseen in determining student preference through their choices was the possibility that some student choices may occur simply because of the possibility of having a choice. In order to determine if students preferred audio on or off, some lessons were repeated using opposite default conditions. Audio would be turned off for one use and turned on for the following one. Occasionally each half of the class would begin with the opposite default before using the reversed defaults in their second use of the lesson. Student responses would then be analyzed for consistency of choice.

Research Strategy

To provide many experiences of varied auditory presentations, some commercial applications were also employed (see Appendix A). Using both applications and authored lessons, student responses to sound were observed and questioned.

The authored lessons permitted a recording of their choices between visual and auditory material. These were printed into a computer file with the student name, the length of time on the computer, and the choices made during the computer session. This computer tracking was done for all students in the class and the computer printouts were analyzed as part of the data analysis. With these results in hand, I then questioned the three students as to their preference both for the type of voices and the various uses of sound, such as speech in directions, explanations, feedback, oral questions, and auditory redundancy for text support (see Appendix B). The quantitative results from the other students contributed an enriched source for probing questions. Both quantitative and qualitative results provided formative evaluation for auditory use in the current lesson and helped determine revisions and refining of those aspects and selection of new aspects to incorporate into the design of the next computer-based lesson.

Data Collection and Management

Data were collected through field notes of observations and incidents, structured and unstructured interviews of teachers and students, computer records of choices made, student work in the commercial computer applications and a year-end questionnaire (see Appendix C). Handwritten notes were taken in order that the subjects not be intimidated. The field notes dealing with the students were discussed with the teachers in order to allow for their collaborative input.

All student record data and the year-end questionnaire results were entered into a computer spreadsheet program for analyzes of student choices at the classroom level (see Appendix D). The individual student files were also printed and kept. The interview questions and responses were entered into **HyperCard** to provide a simple tool for comparison. Because there were few interviews, this was sufficient for their analysis.

Data Analysis

Data analysis was performed after the classes had completed each computer lesson in order to provide a formative evaluation for the next lesson. Each lesson had teacher planning meetings, student observations, computer tracking of student choices and marks, and student interviews. By following this method, trends in student choices and preferences emerged after three or four lessons. These emergent trends then became matter for student questioning, teacher consideration and computer lesson parameters.

The Pilot Study

In January 1993, I met with the principal and a grade 5 teacher to investigate the possibility of working with the teacher to develop computer-based learning software that would incorporate the learning objectives of the teacher while permitting me to investigate student preferences in the use of auditory presentations. At this time, it was decided that we would proceed and the teacher prepared the topic, a long division drill-and-practice software lesson for review purposes. With the expectation of being granted school district acceptance, the lessons were begun so that once permission was granted, we could begin working with the students. Digitized speech was used in this lesson for directions and for positive and corrective feedback.

In order to follow the guidelines determined in January, I showed the teacher the lesson before it was finalized, to have collaborative input in both lesson choice and design. He suggested that students be told their diagnosed level, that the reward for questions finished correctly include animation and sound and that some directions be reworded for greater clarity. Using his suggestions, I finished the lesson and awaited the permission to work in the school, which came March 8.

The teacher and I made plans to conduct the pilot study during the mathematics lesson times of March 22, 24 and April 5 and 7. On the first day, the lesson was copied into 13 computers. When each half of the class came, they were first taught how to use the lesson. In many cases, they had to be shown how to turn up the sound volume since many of the computers required it. Because I assumed that the students would understand the computer buttons for using audio or visual directions and feedback, I did not point them out at this time.

During the work time, students were taught how to follow the computer directions as well as their division estimates and multiplication. In several cases, students did not hear the directions to click on the dividend or the divisor so I repeated these for them. Because there were only nine computers near the classroom, I had to travel back and forth to be with the other four students working in the other computer area on the other side of the library.

The general atmosphere during this time was one of excitement, yet some frustration with wanting to immediately correct wrong estimates. The computer program required that the multiplication and subtraction phases of the long division process be finished even though students recognized that they had chosen a wrong estimate. Another frustration was in learning to type the multiplied numbers with the integer digit first, followed by the ten's digit, and then the hundred's digit, if needed.

Because we had started somewhat late, half of the class received 45 minutes of computer time. At noon the teacher and I decided that we would give the remaining students some time at the end of the afternoon. Those who did not have to go to a singing practice then came for a 30 minute computer time.

During this noon discussion, permission forms were given for parental approval of three student interviews on two occasions after using the computer program. These students had been chosen by the teacher so that both genders and varying academic abilities were represented but were to have been given the freedom to accept or reject this experience.

During the second day of the pilot study, each half of the class came for a half-hour during the mathematics hour. For this and the remaining times of the pilot study, four more computers were moved into the corridor near the classroom so that thirteen students could work within the same area. Because of their previous experience, the students understood better how to work with the lesson although two students had to be helped to raise the sound level and others reminded of the directions for clicking on the divisor or the dividend. More time could be used for helping students with the mathematics skills required. The greater number of talking computers added to the general noise level but the atmosphere was one of excitement and enthusiasm. Students were very attent to the computer screen.

During the noon hour, in collecting computer data files for both days, it was found that some of the first day's files had been erased, including that of one of the student interviewees. The importance of daily collecting computer data files was realized.

After the noon hour, the three students had individual interviews in the library (see Appendix B). After a short introduction telling the students the purpose of the interview and the desire to ch r feelings about the program—what they liked and what they did not like about it questions were asked. Student names have been changed to preserve their anonymity.

Ann, Jim and Kitty all liked having the computer speak. Ann said, "I like the talking, to know if I got it wrong or not." Jim stated, "I like the talking. We can turn off the sound. I like the choice." Kitty replied, "I find it useful, instead of talking to myself" (Student Interviews, March 24, 1993). Although they were not bothered by hearing neighboring computers speak, only Jim knew that he could turn off the spoken directions to have visual ones instead.

These interview responses indicated that the students were not as bothered by the general noise level as expected. The interviews also demonstrated that students should be shown how to turn off the audio to realize they had a choice between visual and audio modes. Only six of the 23 students had turned off the sound at some time during the two previous periods.

As the next week was Spring Break for all Edmonton schools, the study continued two weeks later, April 5 and 7. The teacher varied which half of the class came first and the students who were chosen to come first came eagerly and enthusiastically. They began the program immediately. Following information gained from the first interview, I asked all the students to turn off the audio directions and audio feedback for at least one question but stated that they could turn them back on again when and if they wished. Two students (including one of the interviewees) kept them off almost the whole time while five more kept them off between 50%-80% of the time. The remaining 16 students ranged between a 50%-97% audio-on condition.

After the noon-hour, the three students were met individually in the library. This time the questions were more open-ended, following the lead of the students, but centering on the auditory presentations. Jim suggested, "I think it would be better to have different voices" but Ann said, "The same voice is OK" (Student Interviews, April 5, 1993). For the repetition of directions, Ann said, "The sound repetition is OK." Jim replied, "I would like the sound repetition to be optional." Kitty made an interesting observation, saying, "I liked the repetition because it was like the teacher talking through a lesson. Just like when I was up at the board and the teacher told me what to do." This time, all three students had the sound off at least part of the time. Kitty left the sound off, saying, "I didn't turn the talking on because I knew what to do" (Student Interviews, April 5, 1993). Her answer indicated that once students know the directions well, they may then tend to ignore the directions. The mode of direction delivery may no longer be of interest to them.

This interview and the study of the computer records of students' previous performances, it was noted that many students did not finish the four practice exercises. Therefore, the program was revised before the last day. However, an unnoticed programming bug led to student frustration. On this occasion, the students used the revised program containing only two practice questions. The audio mode for the directions was turned off while the audio mode for the corrective feedback was left on. Because directions to click on the divisor and the dividend were considered essential and because many of the students were not hearing them, they were changed to visual directions. Two students noticed this and wanted to turn them back on to audio.

The students were quite enthusiastic with their student levels, with many of them achieving a mastery level for the first time. To achieve this level, they could have no more than one error in any area: estimation, multiplication or subtraction.

When the students arrived at question 5, the lesson stopped moving forward through the question types. Some of the same word problems, with different numbers, were presented for a second and a third time. At this point, some of the students became restive. The students were asked to keep on for a few more questions to have 10 questions done and the second group was warned of this problem in the lesson before they met it.

After this noon-hour, I met with the principal and the teacher to give the former an immediate oral report of what we had done and to describe the student reactions to the pilot study. We then discussed the expansion of this pilot study into a full study the following year. One teacher in each of the two grades would help to develop materials but students of other classes in the two grades could use the program as well. I would be in the school two days each week. The choice of teacher for the other grade and the specific days of the week would be determined at a future time.

Conclusions and Directions Given by the Pilot Study

From the student behavior and the student interview data, it seemed that:

a) Sound from different computers did not bother them.

b) It was helpful to have the students explicitly turn off the sound for them to recognize this option.

c) Fifteen of the 21 students exercised the option to turn the audio back on at least part of the time when it was set off at the beginning of the program.

d) Almost two-thirds of the class left the audio corrective feedback turned on (13/21) while three more kept it on over 90% of the time. Only three students had it on less than 25% of the time.

e) There should be consistency in having all directions spoken, but important directions, such as clicking on the divisor or on the dividend, could not be guessed if they were missed. These should be in both visual and audio modes or else repeatable at will.

From this pilot study, it was seen that students could work with sound in a somewhat noisy environment and that they did appreciate the audio component. Most students seemed to prefer the audio mode over the visual mode. They liked having control and did not seem to mind corrective feedback being given orally.

These tentative conclusions led me to have students work without earphones until such a time as they would say they were needed. It also demonstrated that students had to be told about their options and that the default setting of their options had to be varied so as not to bias their responses.

There were other aspects of the use of speech that had not been considered yet, such as a controlled repetition of directions, the effect of the use of visual and audio modes together to present redundant (identical) information as well as many other aspects. These were incorporated in the new lessons prepared in the full study.

Ethical Considerations

In order to protect the six interviewed students, both they and the school had to be anonymous. For the purposes of my dissertation, the teachers also had to remain anonymous. However, if they wish to collaborate in later published articles, they might wish to use their names (Shulman, 1990). This could be done, providing that the article is written in such a way that the six students cannot be identified.

The approval of the six students' parents and of the teachers was obtained before the study began and all were told that they could withdraw at any time without harmful results.

The classroom teachers could not be hindered nor could the research be detrimental to either teaching or learning within the classroom. Thus, the schedule was adapted so that it would not harm either the teachers or the students. As the teachers' collaboration was essential in this study and determined the content of the lessons, it was important that they view this study positively and that it could also meet some of their needs.

Some inservice opportunities were offered as part of what I could bring to them. In turn, the teachers accepted me into their school culture. As it was a new school, in its second year of operation, this was an exciting opportunity for me.

Limitations of the Study

Merriam (1991) listed many limitations of case studies, some of which can be minimized by careful or conscientious planning. Rich, thick descriptions and analysis require time and can be too lengthy or detailed. Care was taken in this study to keep the material simple yet interesting.

Case studies can oversimplify or exaggerate a situation or can be presented as a complete report of a state of affairs whereas they are only a part of a reality. Care was taken to point out the boundaries of the case and those aspects of the phenomenon not pursued because of time requirements or other limitations.

Case studies are limited by the sensitivity and integrity of the investigator. The collaborative nature of this study, with student results being reviewed by the teachers, enabled me to gain insights I would have missed and placed checks on my veracity. The gathering of corroborative evidence through direct observation of all the students, computer tracking of choices and questioning, and the year-end questionnaire provided a means of triangulation to ensure the reliability of the data.

The final limitations of generalizability and validity can be addressed only through the internal consistency of the conclusions arising from the data. The use of both grade 5 and grade 2 classrooms in this study should strengthen its usefulness for other settings. The collaborative nature of teacher and students with a software designer may have potential for other studies researching varied phenomena. However, care had to be taken to ensure that the parameters of the study were well stated so that researchers will not seek to apply the conclusions for this group to another. Care was also taken to faithfully report the strategies for data collection and analysis.

The next chapter will provide a description of student observation and my view of the year's experience. It will also contain a description of changes in the research method that occurred during the process.

CHAPTER 4

OVERVIEW OF THE DEVELOPMENT OF THE COMPUTER LESSONS

Because the focus of the research was on auditory presentations in computer-based learning, this chapter will cover all other aspects of the research in order to give a framework for the more focused descriptions in the next two chapters. Therefore this chapter will review the general aspects of the study, including descriptions of the classrooms, of the six representative students chosen to be interviewed, and of four representative computer lessons within a narrative of the year's experiences. It will then conclude with a general summary of student responses to their experience of this research.

Description of Classes and Student Interviewees

The same teacher who had been involved in the pilot study wished to participate in the full study as well. His grade 5 class during 1993-1994 contained 13 boys and 15 girls from differing cultural backgrounds and demonstrating a wide range of abilities. One student with a hearing handicap had an adult aide for sign language interpretation.

The whole class cooperated very well in the study, using each computer lesson fully and often repeating it voluntarily when time permitted. When the computer became stuck because of an error in programming, the students accepted to quit and start again. With few exceptions, described later, students were well behaved and worked well without full supervision, which was necessary because of the previously mentioned computer placement.

The grade 2 teacher's class contained 10 boys and 11 girls with a similar variety of cultural backgrounds and range of abilities. While six students were receiving special help from the resource room teacher, an equal number were considered gifted.

Each teacher was asked to choose three students according to the criteria mentioned earlier. Both teachers chose two boys and a girl, whom I will name Harry, Sam and Teresa in grade 5 and Carrie, Larry and Peter in grade 2.

Harry was a student who generally comprehended concepts quickly. Friendly, attentive and respectful, he aimed for high marks and would repeat the computer lessons until he achieved a score of 100%. Very articulate, he was willing to criticize the lessons and often offered appropriate suggestions for their improvement. His average score was 84%.

Sam was a student who had difficulty learning yet he also was eager to please. When a simpler version of a lesson was given, he redid the harder version that had been used the previous day. He was not always able to finish the lesson in the time given but was always willing to interviewed. Although he was not as articulate as the other students, he was willing to give his opinions. His average score on the computer lessons was 57%.

Teresa was an average student who worked very well. Eager to please and very conscientious, she generally tried her computer lessons again several times to improve her mark. Very articulate, she volunteered thoughts and feelings about computers and computer lessons. Her average score was 79%.

Carrie was a gifted grade 2 student. She was keen and finished quickly. Her careful work and conscientious attention helped her achieve consistently good results, giving her an average score of 86%.

Larry was a shy student, slow in expressing himself. His interview answers were usually a single word response, although occasionally he would offer an explanation for choices he had made in a lesson. A quiet, consistent worker, he achieved an average score of 79%.

Peter was also a gifted student. He seemed very familiar with computers and would experiment with the various options offered in the lessons. His interview answers were always short and to the point. Peter's average score was 89%.

A ajor part of the time commitment to this research was invested in the creation of computerized lessons on topics requested by the two teachers. This time was crucial, as decisions made about lesson design, educational objectives, artistic presentation and audiovisual choices would have an effect on student acceptance and enthusiasm. A serious flaw in the first three elements could deter students from the cooperation necessary to develop criteria for auditory presentations from their audiovisual preferences. The next section describes the steps involved in the creation of the computerized lessons.

Description of the Lesson Creation Process

During this study, the initial step in creating a new lesson was to dialogue with the teacher to determine what would be suitable for the class. The teachers would give the topic to be covered and resource materials for content, focus, and suggested procedures. This included copies of selected pages from course outlines, textbooks, worksheets or sample questions.

With these materials, the lessons were then created and developed (see Appendix A for a complete listing of the lessons). Pictures and available content were examined and occasionally supplemented with material from the University curriculum library. The flow of the lesson and the extent and type of auditory presentations were then planned on paper. One priority in lesson design was making the lessons as interactive as possible, with many student responses, to maintain constant involvement and reflection. Another was to make lessons attractive by the creation of colored graphics. Because of the scarcity of interesting and instructive graphics, pictures were occasionally scanned from textbooks or library books. This use of a scanner presented me with an ethical and legal dilemma.

According to the US fair use guideline, a teacher may copy material provided the copying is spontaneous and the amount copied meets the brevity and the cumulative-effect standards (D. F. Johnston, 1978, p. 92). Spontaneity means that the copying is done so close to the time of its use that there would not be time for obtaining permission. Brevity requires that no more than one illustration per book be used while the cumulative-effect requires that no more than two excerpts can be taken from one author per class term. Section 107 of the US Copyright Act of 1976 describes four factors to consider for fair use: 1) the purpose of the use, whether for commercial or nonprofit educational purposes; 2) the nature of the work being copied; 3) the amount of the portion copied relative to the whole; and 4) the effect of this use on the potential market (Cited in Lawrence, 1980, p. 10; Sinofsky, 1988, p. 38).

According to the Canadian copyright law, fair dealing is "the quotation from, or reproduction of minor excerpts of a work in which copyright exists for bona fide purposes of private study, research, criticism, review or newspaper summary" (Consumer and Corporate Affairs Canada, 1992). According to Harris (1992, p. 110) "fair dealing" is much narrower than the US "fair use" guidelines and does not extend to teachers' making multiple copies for class use. In order to enable immediate access to up-to-date materials in education, copyright collectives can enter into a license with a Minister of Education in a province. This has occurred in Alberta with the Canadian Copyright Licensing Agency (CANCOPY, 1993). This license, valid until August 31, 1996, authorizes the making of copies for each student in the class of "an entire short story, play, essay, article, poem, or item of print music, from a book or periodical issue... containing other works; an entire newspaper article or page; an entire entry from an encyclopedia, dictionary, annotated bibliography or similar reference work; an entire reproduction of an artistic work ... from a book or periodical issue containing other works; and an entire chapter of a work" except for specific excluded works. This copying is defined to be "the making of visually perceptible facsimile copies" by any mechanical, electronic or physical means. In a further section of the license, the Agency states that any input of published works or material into a computer is only for the purpose of making copies and should be erased from memory immediately after output. This would seem to indicate that, although Alberta teachers can make multiple copies of pictures, scanning them instead into a computerized lesson for these same students is not accepted. This method of reproduction is not discussed in the license. This may be because of computer lessons' non-tangible, unlimited mode, with a networked lesson simultaneously accessible by multiple users in various classes. US copyright law is lenient for the copying of a few pictures for a lesson as long as it is only a small portion of a work for a non commercial use and there is insufficient time to obtain permission. However, it also does not seem to consider scanning pictures into a computerized lesson.

As scanning graphics seemed to be an infringement of both Canadian and US copyright laws, they were considered the last resort for obtaining educational graphics. Two clip art collections were bought: **Key ClipMaster Professional Image Library**, a database of clip art copyrighted by Metro Creative Graphics, and **Clip Art [illegible].0** (1992) copyrighted by EDUCORP computer services.

Once the lesson design was determined, the lesson was created within an authoring system, either **Authorware Professional** or **HyperCard**, combining lesson design, text, graphics, and sound. **Authorware Professional** was used in most cases because it provides for tracking student responses and seems to be more suited to interactive lessons with a logical progression. **HyperCard** was used for three lessons that made extensive use of a database format and were not designed to record student responses. Occasional pictures were scanned from the resource materials but most pictures were drawn or were chosen from the clip art collections. These various graphics were then colored in **SuperPaint** before being pasted in the lessons. This preliminary graphic work took two days for some lessons. Auditory presentations were created with the computer microphone using Authorware's **SoundWave**™ application. Speech was recorded at 22.2 kHz, edited to delete long pauses, and then resampled at 11 kHz to halve the storage requirements. During programming time, lessons had to be checked often for errors and for artistic qualities. The time used for lesson design, graphics and speech preparation, and computer programming was 556 hours. Time in the school with teacher and students, 332 hours, was 30% of the total time whereas programming time came to 70%. Lessons developed using an original instructional design took 25 to 30 hours whereas others using a design similar to a previously completed lesson took 5 to 6 hours.

Once ready, lessons were tested by three adult volunteers who checked for the intuitiveness of responses and the overall effectiveness of the lesson. After further revision, they were brought to the teacher for further input. Often the teacher would accept them as they were but occasionally there might be suggested improvements.

Description of the Year's Events and Four Sample Lessons

As there are too many lessons to give a detailed description of each one, it would be useful to consider two sample lessons in each grade. Because the majority of the lessons were of the drill-and-practice type to respond to the teacher requests, there will be one of that type in each grade and one of another type. The lesson descriptions will be included within a narrative describing events and student reactions during the study.

I prepared for the study by visiting the grade 2 teacher in August to get the first topic and by sitting in on the grade 5 class in early September. From then on, I prepared and used 28 computer lessons for the two grades, taught **HyperCard** to the grade 5 students so that they could develop a computerized presentation in social studies, taught the grade 5 students spreadsheets in **ClarisWorks**™ to develop graphing skills in mathematics, worked individually using Discis books with special needs students in grade 2, taught the grade 2 teacher to digitize her voice and to create her own spelling list in **Spell-It Plus**™, taught the grade 5 teacher to digitize his voice and to use a **HyperCard** stack created for drilling spelling words, and helped the grade 2 students do wordprocessing on the computer with **KidWorks 2**™. At times, the children were observed working at other subjects to get a better understanding of their abilities and needs. Table 2 shows the distribution of the research time spent in the school and the number of interviews with each grade. The dates of presentation of each lesson are indicated by the lesson name in italics. The same name in ordinary print shows repeated use of the lessons. Sometimes the hours spent in the school were divided between the two grades whereas, at other times, the whole day was spent with one grade. Because conflicting events permitted the grade 2 class fewer days for computer work, they have fewer interviews.

As happens in all elementary schools, many events occur to disrupt a teacher's schedule. Having a student teacher presented the grade 2 teacher with extra activities that resulted in one missed opportunity to work with the grade 2 students in the fall. On other occasions, a skipping rope demonstration, a Chinese dragon dance, a class visit to a pond, student involvement in singing competitions, student holidays for teacher conventions, and report card interviews prevented work with one or both of the classes. At all times, the teachers graciously allowed adjustment of the school schedule to permit my work with the children.

Table 2. A timetable of school observations and computer work

Date	Grade 2	Date	Grade 5
		Sept 9	*Spider report* in HyperCard
Sept 14	*Rhymes/Rhymes2* (3 students)	Sept 14	Teaching HyperCard
Sept 16	Rhymes/Rhymes2 (all)	Sept 21	*Spelling 100*
Sept 21	Rhymes/Rhymes2. *Spelling 1*	Sept 23	*Place Values*
		Sept 30	Place Values
Oct. 4	Discis Books	Oct. 7	*Rounding off*
Oct. 12	*Blends 1, Blends 2*	Oct. 12	*Explorers, Division*
Jan. 31	*Canada Quiz*	Feb. 3*	*Punctuation Tutorial*
Feb. 7*	*Making Change*	Feb. 7*	Punctuation Tutorial
Feb. 10	Making Change	Feb. 10	Punctuation Tutorial
		Feb. 15	*Sentence Tutorial*
		Feb. 17*	Sentence Tutorial
Feb. 22*	*Fractions*	Feb. 22*	Sentence Tutorial
Mar. 7	Blends-1, Spelling (7 students)	Mar. 7	*Metric City*
Mar. 10*	Blends-1, Spelling	Mar. 10*	Metric City/*Metric Town*
Mar. 21	Wordprocessing work	Mar. 17	Spreadsheet work
Apr. 5	*Arithmetic.2*	Apr. 5	*Respiratory System*
Apr. 7*	Arithmetic.2	Apr. 7*	Respiratory System
Apr. 14	*Blends 3*, 1, 2, Spelling (7 only)	Apr. 14*	Respiratory System
Apr. 18	Blends 3, 1, 2, Spelling	Apr. 18	*Atoms & Molecules*
Apr. 21	Ear Tests at University	Apr. 21*	Atoms & Mol./Ear Tests
Apr. 25*	*Spelling 2*	Apr. 25	Spelling 2
Apr. 28*	*Spelling 3*	Apr. 28	Atoms & Mol./Spelling 3
May 2	Spelling 2, 3	May 2	*Missionaries* (half class)
May 5	Spelling 2, 3	May 5	Missionaries (other half)
May 10*	*Spelling 4, 5*	May 12	Spelling 4, 5 (half class)
May 12*	Synthesized vs Digit. Speech	May 16	*Food Groups*
May 26*	*Ponds* / Final Interviews	May 19*	Food Groups
June 6	Class Questionnaire	June 6*	Spelling 4, 5 / Class Q. Synth. vs Digit. Speech
Summary	*9 Interviews *14 Lessons*		*10 Interviews *14 Lessons*

After the initial interview with each teacher for materials and time spent in each classroom and with students at the computer, three lessons were developed in September. These were: **Rhymes/Rhymes2,** a drill-and-practice to help grade 2 students pick out rhyming words; **Spelling 100**, a drill-and-practice for grade 5 students of 100 commonly misspelled words; and **Place Values**, a drill-and-practice for grade 5 students in recognizing the places and spelling the names correctly.

Half of the grade 5 class worked at the computer while the other half was taught by the teacher. At the half time of the period, the groups switched. One-third of the grade 2 class worked at the computer at a time so that they could be given greater amounts of individual attention. On some occasions the little group was kept together until finished; on others, students left and were replaced individually.

During the work with the first lesson, **Rhymes/Rhymes2**, student files were stored on each computer and later copied to a diskette. When **Place Values** was first being used, all student data records were sent to a folder on the network so that file copying could be streamlined. However, the network refused repeated student access to the designated folder and all student data for **Place Values** was lost. Therefore, the previous method of storing student files on each computer was continued until there was more time to learn how to work with the network.

In October, a second mathematics drill-and-practice lesson, **Rounding Off**, was developed, as well as two phonics drill-and-practice lessons, **Blends 1** and **Blends 2**. With resources provided by the teacher or from the University's curriculum library, **Explorers**, a set of adventures based on the early Canadian explorers, was prepared during the summer for use in November. This lesson, given to the teacher during October, contained a quiz, a library section to help students, and five adventures in which students could travel with an explorer and answer questions or make decisions that affected their score. The choice of adventures, the taking of the quiz, and the number of quiz questions were placed under the control of the students by providing choices in a menu. Students controlled the option to use the library for research whenever they were asked a question during the adventures. On my return in January, I was told that the grade 5 students had used and enjoyed it.

Between October 24 and January 23, 1994, I was visiting various cities in Argentina and Chile. Although my trip was not connected to my research, it provided an opportunity to speak with a computer teacher in each country about his use of computers within the curriculum and to visit a computer lab in Argentina where children between the ages of four and five were observed using a few, unmatched computers with very little software. Enriched in many ways, I returned to Canada and my research with gratitude and a stronger conviction of the need, when possible, to integrate computers into the curriculum with appropriate computer software.

Although arriving from Buenos Aires, Argentina at 9:45 p.m., January 23, after a trip of 32 hours and a jet lag of five hours, I went to school the next afternoon to get material for the next lessons. The grade 2 teacher requested a quiz on Canadian facts for social studies and the grade 5 teacher, a drill-and-practice lesson to help them develop proofreading skills in language arts. Needless to say, nothing was achieved during the first two days. **Canada Quiz** was developed for the next Monday and **Punctuation Tutorial** for the following Thursday. The latter, a sample of the drill-and-practice lessons, will now be described.

Punctuation Tutorial

In this lesson, after registration, students began the lesson proper with six sections.

- Part I. Common and Proper Nouns
- Part II. Rules for capitalization
- Part III. Sentence types (exclamation, question, command and statement) and punctuation. Figure 6 is an example of an exercise in this section.
- Part IV. Apostrophes for possession and contractions, including it's and its.
- Part V Quotation marks and punctuation
- Part VI. Rules for using commas with dates, addresses, lists, in direct address, sentence interrupters. Figure 7 is an example of an exercise in this section.

In each section, students were presented with several randomly chosen exercises, with corrective feedback suited to that section, as shown in Figure 7. If students did not achieve a predetermined mastery level, they were presented with a tutorial in which they had to respond interactively with an example of each part of the grammar rule for that section. Students were then given a few more questions randomly chosen from a new list for extra practice.

At the end of the six parts, students were given two expert questions that combined capitalization rules, rules for commas, quotation punctuation and sentence punctuation. Figure 8 is an example of one of these questions. Students were required to click on words or drag their punctuation choice.

Figure 6. An exercise in part III of **Punctuation Tutorial**

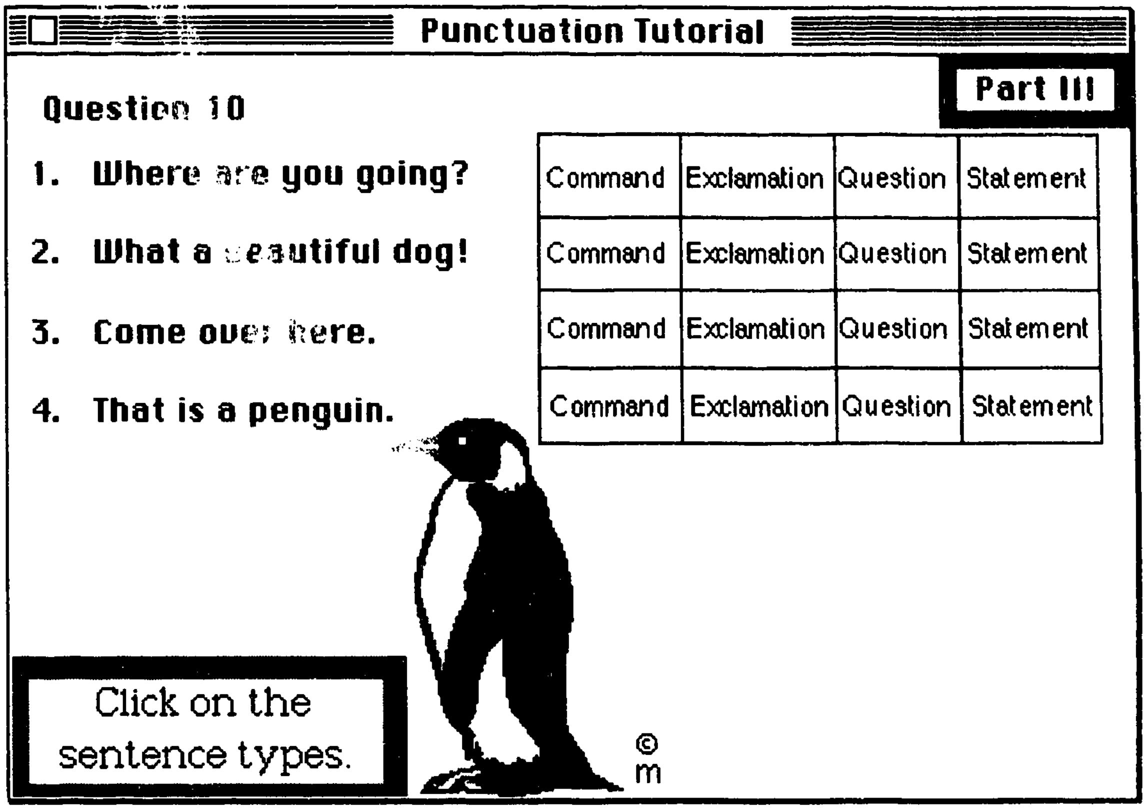


Figure 7. An exercise in part VI of **Punctuation Tutorial**

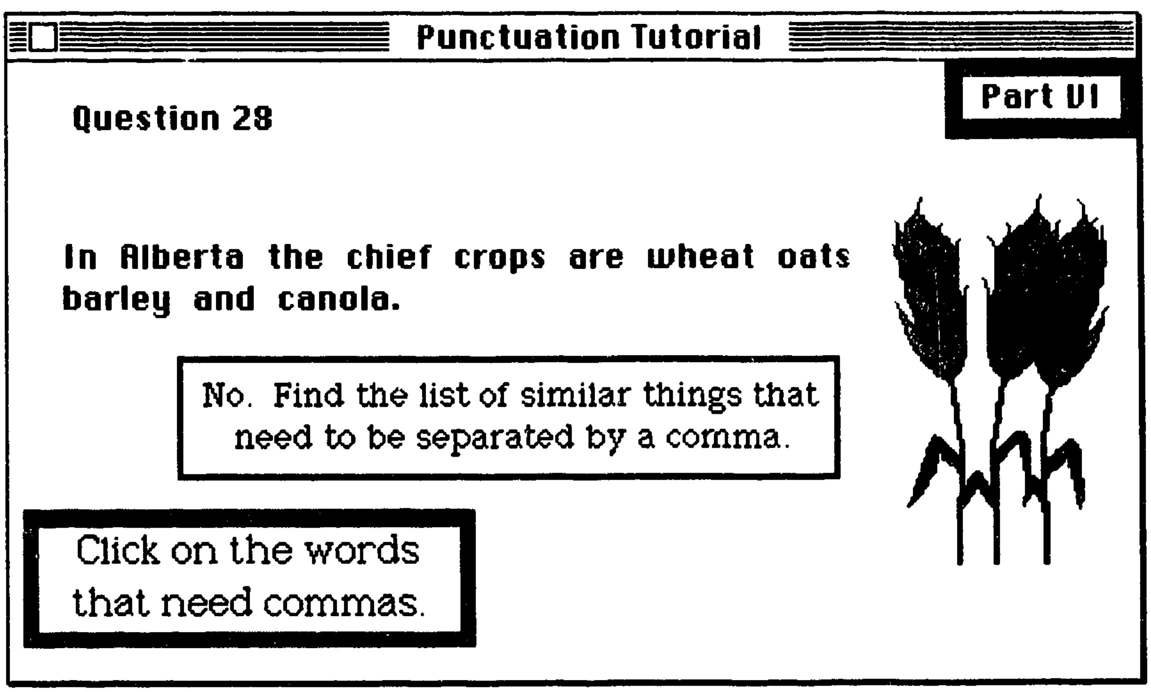
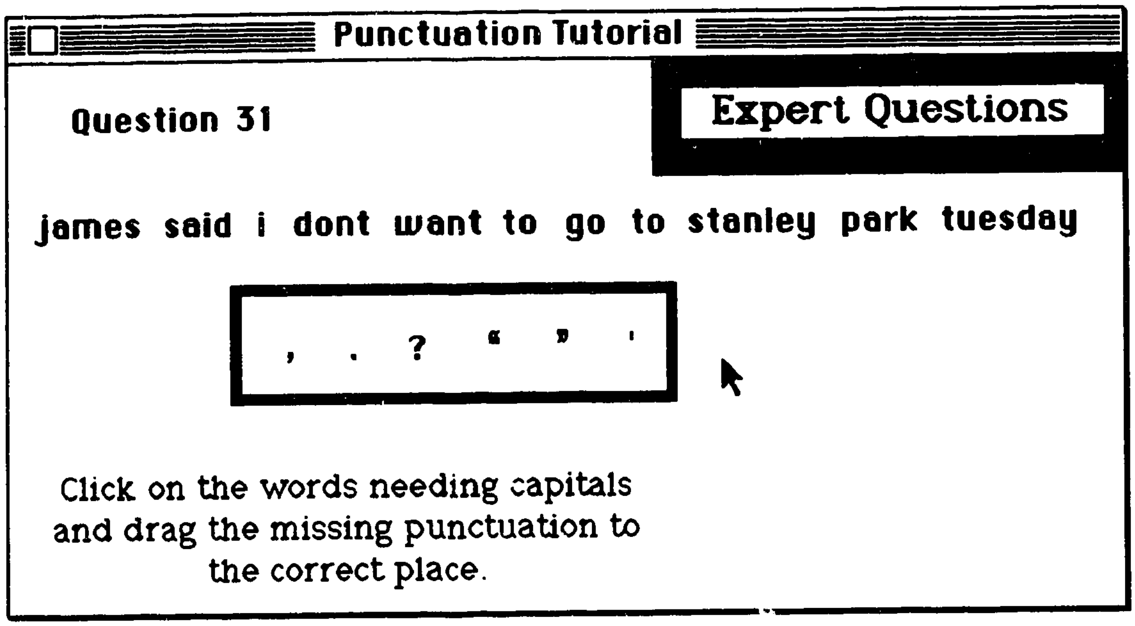


Figure 8. An expert question of **Punctuation Tutorial**



The questions, randomly chosen from a small pool of questions, provided the students with variety while colored pictures in the pretest part added to the lesson's interest. A variety of responses, including clicking on words or dragging punctuation choices, encouraged attention and students were very intent on the lesson as they worked through it. They had difficulty with the dragging responses on their first trials and, at first, punctuation occasionally disappeared when dragged because of a programming bug. At the end of the lesson, the student was told the percentage of correct answers given.

The lesson stored a record of the student's time, percentage and each tutorial they were required to review. The reason for recording the required tutorials was for the teacher to see which areas needed to be stressed and which students were having consistent difficulty with a particular aspect of punctuation. Table 3 is a sample of a student data file. The computer kept a record of her time when starting each section.

Table 3. A sample student data file for **Punctuation Tutorial**

Mary Jones	Thursday, February 10, 1994	10:40 AM
Remediation required	Cumulative Time	Final Score
tutorial on capitals	10:43 AM	
tutorial on quotations	10:48 AM	
tutorial on commas	10:52 AM	
End of lesson	10:55 AM	67%

From individual student data files, a class list was compiled using a spreadsheet program. The grade 5 teacher was impressed by the increase in the mean class scores over three uses of the lesson (55%, 70% and 78% respectively) and the concurrent decrease in mean times (27, 20 and 15 minutes respectively). Part of these results may come from having to learn the lesson. A better comparison of content learning would be achieved by viewing changes in mean score between the second and third use of the lesson.

Interviews with the grade 5 students were conducted after using this lesson (See Appendix B for a complete listing of all interview questions and responses.) Because it was their first interview, general questions about computer lessons and the use of colored graphics were included. All three students liked using the computer. Harry said, "It's fun. I can make choices and it can make suggestions for answers." Sam stated, "I learn more in math and other subjects. Games help me learn." Teresa said, "It's more interesting. I can learn better by reading than by hearing the teacher. It gets my attention" (Student Interviews, Feb. 3, 1994).

All three students liked having pictures, especially colored pictures, but Harry and Sam wished that they would "go with the question" while Teresa saw pictures as motivational: "The pictures help get my attention and give me ideas" (Student Interviews, Feb. 3, 1994).

Immediately after creating **Punctuation Tutorial**, a lesson for the grade 2 class was begun. Although a drill-and-practice lesson, it also has a tutorial component and is an example of the materials presented to the younger students. An interesting aspect of the development of this lesson was the scanning of Canadian coins with a color scanner. An hour was spent digitizing five coins but the results could not be used because they were not clear enough and they used too many colors so that the pictures took a great deal of storage space. The scanned outline of only the Canadian loony was used with the interior redrawn and colored. The other coins were scanned from black and white drawings, retouched, and then colored.

Making Change

This lesson, requested by the teacher to help students recognize Canadian coins and learn to make change, was a drill-and-practice lesson with a tutorial component. The materials given included worksheets in which students were to cross out the coins they needed for an article. This basic format was used in the first part of the computer lesson but a short tutorial on the principle of making change was included before giving some drills on making change. In the original form of the tutorial, the principles were demonstrated in an abstract form. The interviewed students suggested that the tutorial be made simpler so it was changed to include a concrete example.

In the lesson, after students registered, they were presented with four sections:

1) A review of payment was presented, in which the student paid for an article by clicking on the desired coin out of a set on the screen (see Figure 9). As they clicked, a line through the coin reminded them which one they had chosen. A running total shown helped them keep track of their payment. Once the total was reached, the student had to count remaining change: the coins without lines. To provide variety in repeated uses of the lesson, the four questions in part I were randomly chosen from a set of eight.
2) A tutorial for giving change from $2.00 for a 57¢ piece of birthday cake was then presented. This tutorial required the student to click on the required answers in order to proceed to the next step (e.g., 3¢ to make up 60¢). As each set of coins was chosen to make up an amount, the amount representing the values of the coins moved over to the right of the screen where it stayed and the new total was shown. The tutorial ended when the $2.00 amount was reached. The student could look over the steps of the tutorial before going on to the questions in part II.
3) Problems were presented in which students must give change from $1.00. During these questions, the values of the chosen coins were added to the price of the article to reinforce the skill demonstrated in the tutorial. To vary the presentation for repeated use, the three questions presented in this part were chosen at random from a pool of five.
4) Three problems were presented in which students must give change from $2.00. Figure 10 is an example of a question in this part. In all questions in part II, the total count was shown in order to encourage them to count upward from the price charged.

After the ten questions in parts I and II of **Making Change**, students were told their percentage of correct responses.

When the students used the lesson, they "had quite a bit of difficulty understanding what to do at the tutorial section so I found myself teaching them individually. Luckily there were only six students [on the computers] at a time" (Field notes, Feb. 7, 1994).

Figure 9. A sample question in part I of **Making Change**

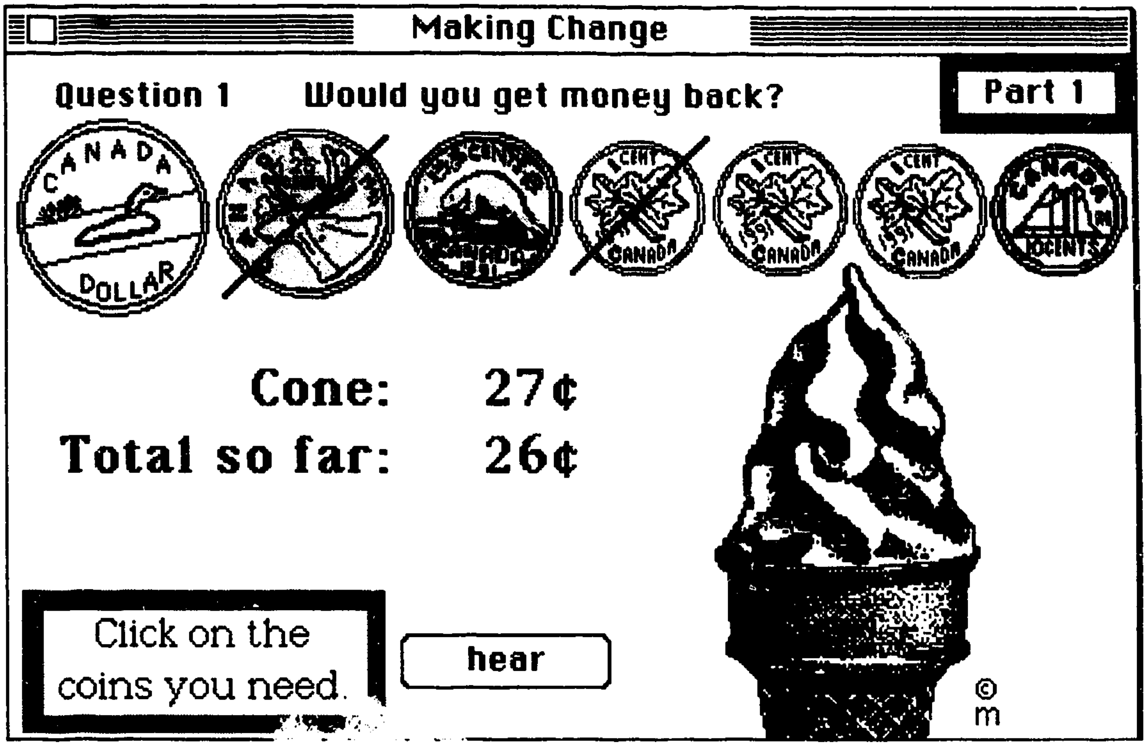
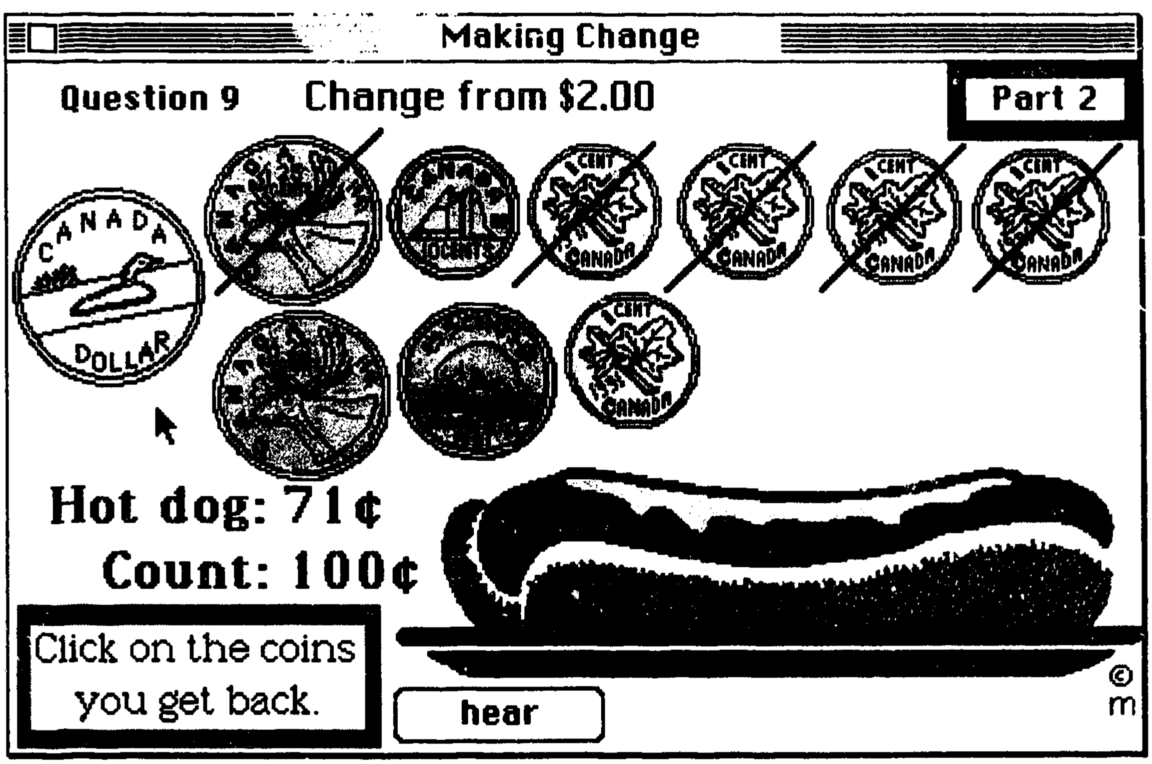


Figure 10. A sample questi[illegible] II of **Making Change**



The lesson kept a record of the student's time and score as well as the number of audio requests. Mean times and scores were then calculated for the two uses of the lesson, giving 13 and 12 minutes, 73.4% and 76% respectively. As can be seen in comparing the values, the grade 2 average scores for this lesson do not vary as much between uses as do those for grade 5 students using **Punctuation Tutorial.**

Because the grade 2 students were being interviewed for the first time, some of the questions dealt with general computer use and computer graphics (see Appendix B). All said that they liked using the computer for learning. Both Larry and Carrie thought it was fun while Carrie added that it was good for education and Peter, that it "helps me do stuff better, quicker, makes me smarter" (Student Interviews, Feb. 7, 1994). As for the pictures, Larry and Carrie liked having colored pictures, although Carrie thought that "with black and white I have to use my own imagination" (Student Interviews, Feb. 7, 1994). Peter, on the other hand, stated that he did not like pictures, just writing.

Questions relating to this lesson dealt with the contrast in oral or visual feedback and criticisms of the lesson. As the audiovisual preferences will be dealt with in another chapter, only the criticism will be considered at this time. Larry had no suggestions for improving the lesson but both Carrie and Peter suggested that some of the questions and the tutorial be simplified. Carrie also asked that there be more questions asked in part I. These suggestions were then incorporated into a revision used Feb. 10. The tutorial was made concrete rather than abstract and subtotals were given throughout the lesson so that children could see how much they had selected.

During the latter half of February, two more lessons were written: **Sentence Tutorial,** similar in design to **Punctuation Tutorial**, and **Fractions.** Because the grade 2 students found the latter somewhat difficult, a great deal of individualized help had to be provided while the students were working. Fortunately, there were only seven students working at a time so those experiencing difficulties could be helped quickly.

During March, grade 2 students repeated the phonics lessons created the previous October. The grade 2 teacher wished the students to repeat the spelling lesson created the previous September as well. Meanwhile the grade 5 teacher requested work in understanding the metric system and **Metric City**, a drill-and-practice lesson within the framework of a search for treasure, was developed. Students found the lesson difficult, as they had to remember many facts, such as, "There are 10 families living on 10 floors of 10 apartment buildings in the 10 blocks of the city," or similar facts from the other two randomly chosen scenarios. These facts were not retained on the screen so that students would have to request either oral or visual repetition. The teacher asked that the lesson be simplified so **Metric Town** was created. **Metric Town** had three factors of multiplication by 10 rather than four, as shown in the example stated for **Metric City**, and had only one scenario, that of students in classrooms in a school. Students were allowed to use either lesson on my next visit.

In April, a new lesson was presented to each of the grades. **Respiratory System** had been requested by the grade 5 teacher who, by now, had a good idea of the computer's and my capabilities. He gave me textbook material and a unit plan with several interesting diagrams. The lesson was created with these materials.

Respiratory System

As shown in Figure 11, the student was presented with a menu with five sections:

1. Definitions of nose, trachea, bronchi, lungs, diaphragm, shown in Figure 12.
2. Animation of inhale and exhale cycles.
3. Animation of oxygen molecules being inhaled and going out to the body cells and carbon dioxide molecules being exhaled.
4. Story of an oxygen molecule going through the respiratory and circulatory systems and a carbon dioxide molecule being exhaled. Occasionally students were asked a short question to check their comprehension.
5. Quiz of 10 questions: four click-on-a-diagram questions to show the position of the required part, six fill-in-the-blank questions about the parts of the respiratory system.

The student was then given a final report giving the percentage right.

The students seemed "quite excited" by the lesson (Field notes, April 5, 1994). Because it was menu driven, the children were asked to go through every part in order to not miss anything but were allowed to choose the order. Some went immediately to the adventure section; a few, to the quiz section first; others, to the definitions.

Because both the spoken definitions and the explanation of the animations were quite long, many of the computers were speaking at the same time. Until this point, students had not had time-intensive speech during the computer lessons. During the next set of interviews, I reflected with Harry on the possibility of using earphones. He thought it was a good idea. Seven pairs of earphones were provided the next time while many students brought personal ones from home. From this time on, students were encouraged to use earphones. However, some students preferred not to use them.

Students seemed to appreciate the quiz section and they improved; the average mark went from 63.6% on the first day to 80.3% and 93.4% on successive days. Students

Figure 11. The menu page of **Respiratory System**

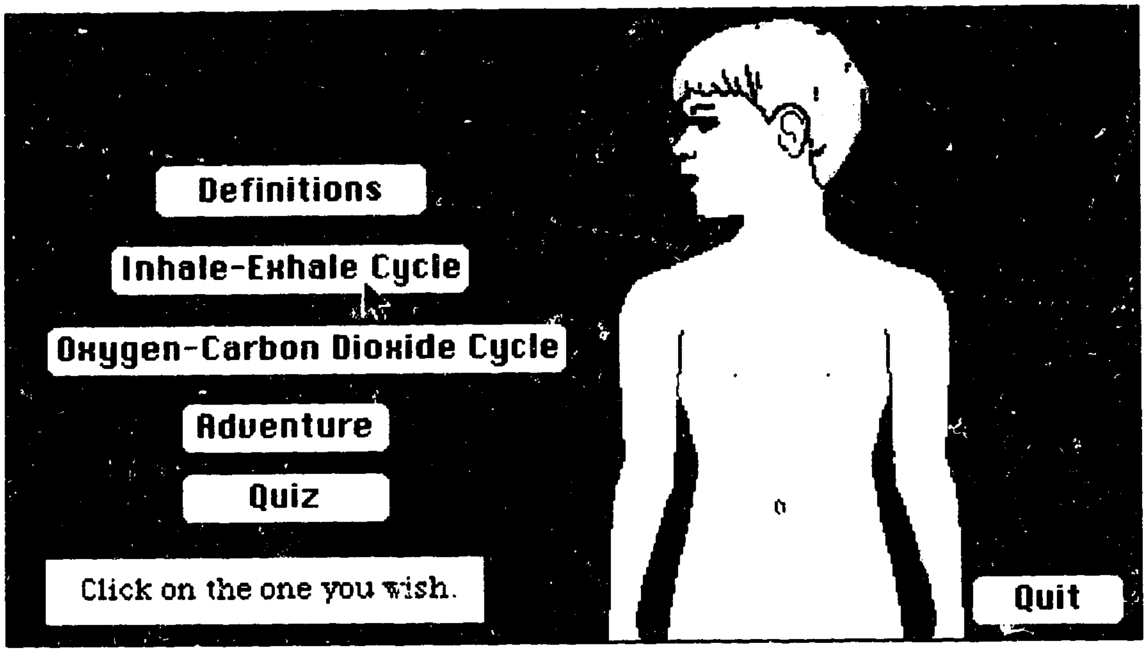
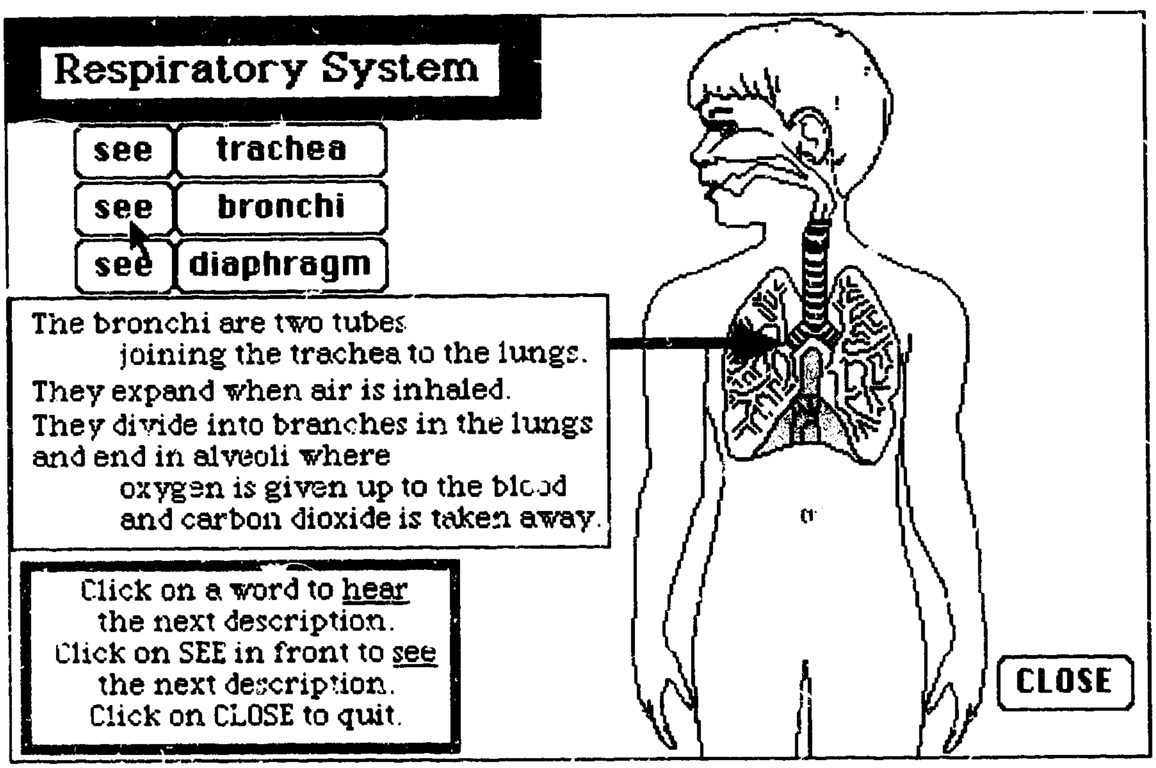


Figure 12. A definition page of **Respiratory System**



also tended to repeat the quiz part of the lesson each day to improve their scores. Ten, 15 and seven students repeated the lesson on the three days respectively.

During April, four lessons were developed for the grade 2 class and two for the grade 5 class. The grade 2 lessons were a drill-and-practice mathematics lesson, **Arithmetic.2**, reviewing the four operations, a drill-and-practice phonics lesson, **Blends 3**, and two drill-and-practice lessons using spelling words provided by the teacher. The grade 5 **Atoms & Molecules** lesson also had a menu format with definitions, animations, an adventure and a quiz.

Also in April, the six students were taken to the University for an audiological assessment consisting of a tympanogram exam to test for ear infection and an audiogram to test hearing. The purpose was to make sure that their hearing fell into the normal range and their opinions about auditory presentations or their choices in audiovisual options were not influenced by a lack of hearing ability. The chart in Table 4 shows all student test results falling within normal ranges for hearing sounds and for distinguishing words. A HTL of 0 dB is considered to be the normal and most normal people's range is between 0 and 10.

Table 4. Hearing test results of the six interviewed students

Student	HTL (dB)	Response Reliability	Response Validity	SRT rt (dB)	[illegible] lt (dB)	[illegible] rt (%)	at dB	WDS lt (%)	at dB
Carrie	-5 to 15	good	good	0	0	100	30	96	30
Larry	-5 to 5	good	good	0	0	96	30	100	30
Peter	-5 to 10	good	good	0	0	100	30	96	30
Harry	0 to 10	good	good	0	0	96	30	100	30
Sam	-5 to 0	good	good	5	5	100	35	96	35
Teresa	0 to 10	good	good	5	5	100	35	100	35

Note: HLT = Hearing Threshold Level

SRT rt = Speech Reception Threshold for right ear (lt = left ear)

At the beginning of May, a social studies lesson, **Missionaries**, was developed with materials from the social studies textbook and the University's curriculum library. Although it could have been developed in **Authorware**, as were most of the previous lessons, **HyperCard** and the format of **Explorers** were used. The latter was a social studies lesson developed for the previous fall. This decision contributed to one of the more harassed moments of the study.

When **Explorers** had been used in the fall, the network capabilities were not used and lessons were copied to each computer. During the winter, a single copy of each lesson was placed in a folder on the network for all students to access. When **Missionaries** was previewed by the teacher from the network, everything worked well with one user. When the 14 students came to use the lesson, all but one computer said that the lesson could not be used because "it was busy." Realizing that the lesson could not run on the network, I immediately asked all students to quit and copy all parts of the lesson to their computers. With students using computers on both sides of the library, including students who did not know how to copy, students who copied only part of the lesson, one student who started using the network version again, there was chaos. While I was trying to determine which student was using the network version, other students were asking my help for copying. Finally realizing that the errant student was not on the left side of the library, I was searching among the other computer users when two grade 5 boys came running down the hall towards me, chasing each other. By the time the student using the network version was found and asked to quit the lesson, the two misbehaving students spoken to, and all the students finally working, half a period had passed and the grade 5 teacher's careful schedule was ruined.

During May, three lessons were developed for grade 2: two drill-and-practice spelling lessons and a tutorial lesson on pond animals and plants, **Ponds**, and for grade 5: a tutorial and simulation lesson in health, **Food Groups**. **Ponds**, the last lesson developed, will now be described.

Ponds

In this lesson, after the students registered, they were presented with a tutorial of five randomly chosen sections: plants, insects, birds, cold-blooded animals and mammals. Each section has a picture of the pond organism, an oral or visual description and its name. There are four plants, five insects, four birds, five cold-blooded animals, and three mammals described in the tutorial section. Figure 13 shows an example of a screen in the tutorial section.

After the tutorial, there is a quiz of 15 multiple choice questions, as in Figure 14, chosen in random order for students to identify the pictures. Each response is given immediate visual feedback with a check or an "x". An ending report gives the student the percentage of questions done correctly in the quiz.

Figure 13. An example question from the tutorial section of **Ponds**

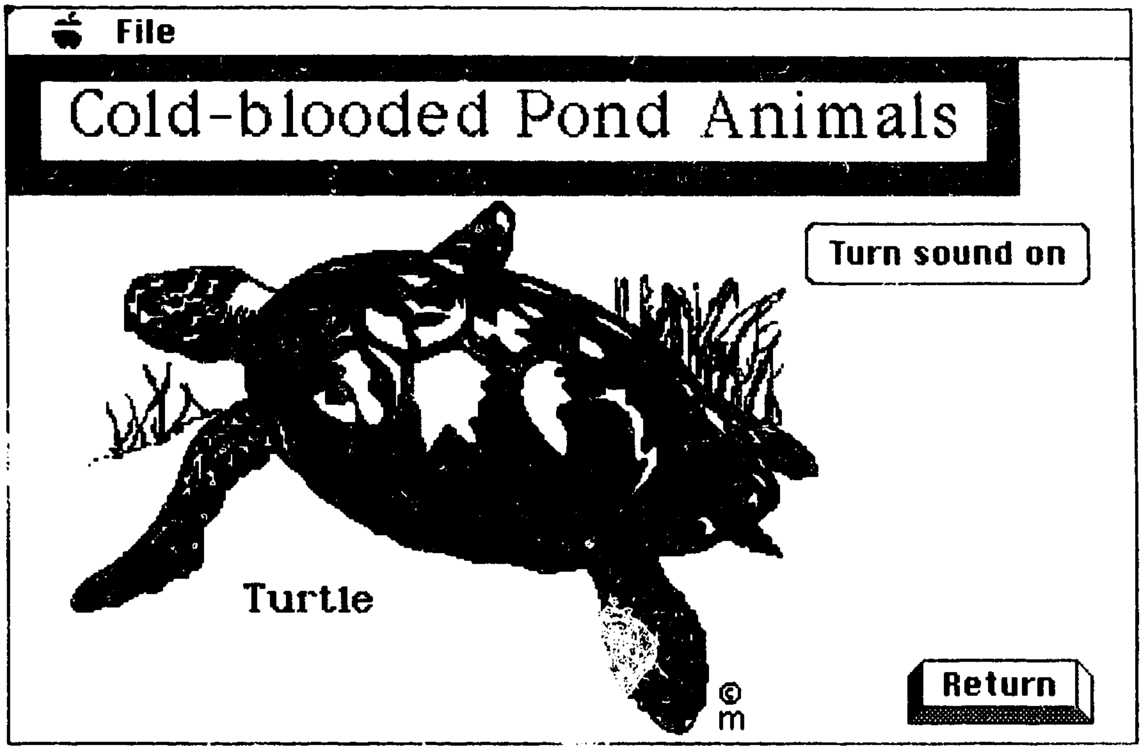
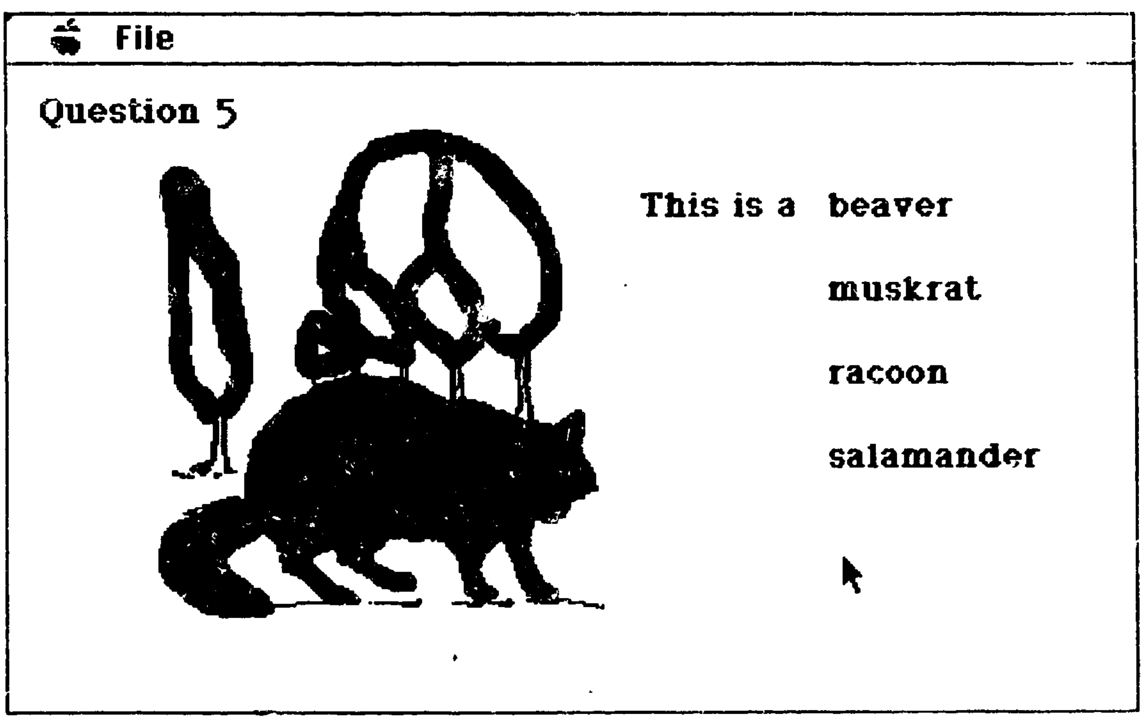


Figure 14. An example question from the quiz section of **Ponds**



All the students seemed to enjoy the lesson, easily accepting to do it twice. Students with sufficient time repeated it a third time. Peter remarked that it was fun while Carrie said, "It was good, neat because it had to do with what we were learning in school" (Field notes, May 26, 1994). In the first two repetitions, the mean scores for the class were 78.5% and 80.6% respectively while their mean times were 5.2 and 4.6 minutes respectively. Again there is not much variation in the mean scores or time.

Summary of Student Responses to the Lessons

Grade 5 students displayed an eagerness to use the computer lessons. When they would see me come into the classroom, they would ask enthusiastically, "Are we going on the computers today?" and occasionally, "Are we getting a new lesson today?" In reflecting on the year's experience, the grade 5 teacher remarked, "The students really liked the lessons. They would get so excited when they saw you coming, and especially when you said you had a new lesson for them" (Final teacher interview, October 5, 1994). Toward the end of the year, one grade 5 girl stopped me in the hall and asked, "Why can't you keep on [with the research]? I didn't use to like social studies and computers, but now I do" (Field notes, May 10, 1994). When grade 5 students stated their preferred lessons, those receiving equal votes were **Place Values, Explorers, Metric City/Metric Town, Atoms & Molecules** and **Food Groups**. Student comments were: "They were fun", "They really helped" and "I learned a lot from them" (Field notes, June 6, 1994).

The grade 2 students seemed quite eager to come to the computer but quickly became bored with lessons longer than 15 minutes or those that were being repeated. They generally worked quietly, even for long or repeated lessons. The most difficult lessons for the grade 2 were the spelling ones in which they had to type the required words. One student had an arduous time and would search for the word letter by letter. She would often become distracted and spend several minutes looking around. Other times, she would erase her work and start over again. While all the other students finished the lesson in 2 to 15 minutes, she took 31 minutes. When asked to choose their favorite lesson, eight grade 2 students preferred **Ponds** because it "helped with my school work", "It was fun", "It tells you a lot of stuff", and "It has all those beautiful pictures" (Field notes, June 6, 1994). On the other hand, five students listed a mathematics or spelling lesson because it helped them with their mathematics or spelling.

From the student response, it can be concluded that most of the students enjoyed the computer lessons. Even though typing skills hampered the grade 2 students in the spelling lessons and could have deterred them from considering computer activities interesting, they had enough other experiences to provide a balanced view. The grade 2 students were always eager to be chosen first to go to the computer lesson.

This response encouraged me to assume that the lesson designs, the educational objectives within the lessons, and the quality of the artistic presentations were sufficiently acceptable that students would be attentive and responsive to the audiovisual choices presented. Boredom could deter students from making choices that reflect their preferences.

Changes in the Research Method

Because there were changes in my role during the course of the study, there were changes in the application of the case study method, in the manner of collaboration of teacher and students, and in data collection. Each one of these will be described in turn.

During the pilot study and before beginning the study, my planned role was to be a lesson designer with teacher input at all stages. When students began to use the computers in the fall, I was asked to teach the grade 2 students how to use the computer and the grade 5 students how to use **HyperCard** to create a social studies report. This, as well as the implementation and formative evaluation of the computer-based lessons and the occasional need to teach content material, involved me in a participant role. This provided an opportunity for field observation of student-computer interaction of all the students in the class and widened the scope of my observations. The field observation of the ability of students to make reasonable choices when given control led to the increased control of options in later lessons. This also fit in with my philosophy of viewing the students as active agents of their learning within the cognitive learning theory. Only one time did I observe a poor student choose to use a more difficult version of a program. The main problem observed with determining student preferences through giving them control of various options was that students would tend to accept default options, either because they were not interested in changing them or because they did not know their options. This tendency was counteracted by having students change the default so that they would know their options and by having different versions of the program begin with opposing defaults.

At the beginning of the study, the case study method was to be applied to only the six selected students who would carry the responsibility of verbalizing their preferences and giving me possible insights into their way of thinking in order to interpret class computer data. With the widened observation scope, each class became a case study unit. The six selected students' role continued to include providing a view of student preferences but it also became that of collaborators in the evaluation of the computer lessons, in the manner of including speech in them, and in the design of new lessons by their suggestions. The grid of auditory aspects for inclusion of speech in the computer-based lessons became important in maintaining a systematic research direction when time constraints and deadline pressures limited reflection time.

Earlier it had been planned that the teachers would determine the content and learning objectives, help provide materials and preview the unfinished lesson for suggestions and criticism. The teachers participated at all levels of the lesson design except for the final preview stage owing to time constraints and the greater participation of students in the lesson evaluation. With the change of case study unit, the teachers were not asked to verify student interviewee responses but instead were given a summary of class results and behavior.

Originally the data collection was to include teacher and student interviews and class computer records. During the year, it expanded to include student-computer interaction, student comments during computer use, a final year-end questionnaire, and final comments in student and teacher year-end reflection.

These changes in the research method enriched the study by broadening its scope and permitting deeper interaction with the various participants. Because the original intention of the study was to focus on audiovisual preferences, the following two chapters will focus on student responses in this aspect only in order to begin developing criteria for auditory presentations.

CHAPTER 5

SEARCHING FOR CRITERIA IN GRADE 5

To prepare for this study, the chart shown in Table 1 was set up to give focus and direction to audiovisual choices in lesson development. Although it continued to guide these choices, some changes were made to the chart during the year. In some cases variations were refined while in others, the number of variations was increased or decreased. Besides the guidance of the chart, other factors that influenced audiovisual choices were their appropriateness to the lesson content and student responses to audiovisual choices in previous lessons. In this chapter, student responses to each aspect of Table 5 will be discussed in turn.

Choice

The aspect of choice is important to this study, not just because choice provides for student control, but also because it reveals student preferences and provides corroborative support for student interview responses. All lessons created during the year had at least one use of auditory presentations. In all lessons, except for **Punctuation Tutorial,** students were given choices for visual or auditory mode. I decided not to provide choices in presentation mode in **Punctuation Tutorial** so that students could experience the relationship of its lack of options to those provided in a similar lesson, **Sentence Tutorial**, given shortly afterwards.

Choices of visual or auditory mode were presented to students in four ways. Some lessons forced a choice of mode. Lessons enforcing choice, such as **Metric City/Town** in its hints and corrective feedback, required students to select their preferred presentation mode at each request. A second type of choice, in lessons such as **Place Value** in its directions, **Rounding Off** in its explanations, and **Atoms & Molecules** in its definitions and explanations, offered the opportunity to hear or see presentations only if students wished. Students could continue the lesson without asking for either mode of presentation. A third type of choice in lessons such as **Respiratory System** and the spelling lessons, permitted students to change a pre-designated or default setting. A fourth type of choice, used in **Explorers**, **Missionaries**, and **Food Groups**, was to present options for audio support.

Student records show that students made varied use of the second and third type of choice. In an example of the second type of choice, two and 17 students did not request oral or visual presentations in **Rounding Off** during its first and second uses respectively.

Table 5. Grade 5 lessons incorporating various aspects of auditory presentations

Aspect	Variation 1	Variation 2	Variation 3
Choice	*modal preference*	*audio required (no choice)*	
	Place Values Rounding Off Metric City/Town Respiratory System Atoms & Molecules Spelling 2 - 5	Place Values Rounding Off Punctuation Tutorial Respiratory System	
	audio default	*visual default*	*audio support*
	Sentence Tutorial Spelling 2 - 5	Food Groups Spelling 4 - 5	Explorers Missionaries Food Groups
Audiovisual redundancy	*audio and text given*	*audio and graphics*	
	Explorers Missionaries Spelling 2 - 5 Food Groups	Respiratory System Atoms & Molecules	
Length of speech	*0 - 5 seconds*	*5 - 10 seconds*	
	Place Values Rounding Off Explorers Punctuation Tutorial Sentence Tutorial Missionaries Spelling 2 - 5 Food Groups	Metric City/Town Respiratory System Atoms & Molecules	
Speaker	*male adult, digitized*	*female adult, digitized*	*synthesized speech*
	Spelling 100 KidWorks 2	all lessons	KidWorks 2

(Table 5 continued)

Aspect	Variation 1	Variation 2	Variation 3
Frequency of auditory directions	*every time* Spelling 2 - 5	*once only when new directions needed* Place values	
Feedback (positive - corrective)	*speech - speech* Place Values Spelling 2 - 3	*speech - visual* Rounding Off Punctuation Tutorial	*visual - speech* Sentence Tutorial
	visual - visual Sentence Tutorial Metric City/Town Spelling 2 - 3	*speech - non-speech audio* Spelling 4	
		non-speech audio - speech Spelling 5	*deferred feedback* Respiratory System Atoms & Molecules
Hints/suggestions	*audio and text* Explorers	*audio or text* Rounding Off Sentence Tutorial Metric City/Town Spelling 2 - 5	
Preference for type of use	*directions* Spelling 2 - 5	*explanations* Respiratory System Atoms & Molecules	*hints/suggestions* Metric City/Town Spelling 2 - 5
	positive feedback Punctuation Tutorial Spelling 2 - 5	*corrective feedback* Place Values Sentence Tutorial Spelling 2 - 5	*text support* Spelling 2 - 5 Food Groups

For an example of the third type of choice, student records of the spelling lessons show that one student used the default settings in **Spelling 2**, none in **Spelling 3**, four in **Spelling 4** and three in **Spelling 5**. All other students changed these settings. The use of the fourth type of choice will be discussed in the section concerning audiovisual redundancy.

The three students interviewed also had some preferences about choice. At an early interview, Teresa stated a need for a choice of the visual mode in all presentations because "with Tim [a deaf student, name changed] in the class we need to be able to see them" (Student interviews, Feb. 17, 1994). In comparing **Punctuation Tutorial** and **Sentence Tutorial** in which the former gave no choice of feedback presentation mode, Harry and Sam preferred having a choice while Teresa said that it did not matter if there was no choice (Student interviews, Feb. 22, 1994). Because she had already stated that Tim should be taken care of, her second statement must be taken as relating only to herself. However, in speaking about a later lesson, **Respiratory System,** which incorporated many uses of speech, Teresa stated, "I liked having choices best" and "There should be choices" (Student interviews, April 7, 1994). The former response was to a question specifically concerning variety while the latter was volunteered after she had answered another question not referring to choice.

In the final questionnaire, the class responded favorably to having choice in receiving auditory presentations. Seventy-eight percent of the class stated a preference for being able to have directions said only when they wished. Eighty-five percent showed a preference for being able to differentiate between uses (i.e., turning sound on for some uses and leaving it off for others). All students stated that they wished to be able to control sound at any time during a lesson.

These responses indicate that students want control of presentation mode and that they made good use of their options. They were not constrained by the default settings but felt free to change them. Both visual and auditory presentation modes must be offered to provide options for students with special needs.

Audiovisual redundancy

This aspect includes both audio support of text and audio support of graphics. Apart from the optional hearing of written sentences in the spelling lessons, only two lessons, **Explorers** and **Food Groups,** had simultaneous reading of text material on the screen. In a slightly different type of textual support, both **Explorers** and **Missionaries** had optional announcements of changes in their characters' numerical points during the adventures. In no lessons were students required to have audio support; rather, most lessons required a choice between visual and auditory presentations.

Because it was assumed that most grade 5 students would not need audio support of text, I was interested in providing audio support of an animation and audio explanations of complex graphics. Two lessons, **Respiratory System** and **Atoms & Molecules**, had extensive auditory and visual explanations of graphics that required a modal choice on each occasion. This type of support will be considered after audio support for textual material.

Because **Explorers** and **Missionaries** did not create student records, only student records of **Food Groups** will be considered in studying student preference for audio support of textual material. When audio support was on by default in the students' first use of the lesson, two students, including the deaf student, immediately turned it off, three students turned it off after they had done 85% or 90% of the lesson, and 21 students left it on. On the other hand, when audio support was off by default in their second use, eight students left it off; three students turned it on halfway through the lesson; 16 students turned audio support on within the first screen of information.

Of the three students interviewed, Harry turned it off after doing 90% of the lesson on the first use and turned it on immediately during the second use; Sam kept the default setting in each case; and Teresa, who had been absent the first day, did the lesson twice, the second time turr [illegible] mediately. Harry's reason for using sound was "It is easier to understan [illegible] do work. I prefer it to reading" (Student Interviews, May 19 [illegible] red that there was more information in the auditory version [illegible] and Teresa said that there was not. Although Sam did not chan [illegible] second use, he stated that he wanted sound and considered it [illegible] e need for some audio support of text saying, "Some peo [illegible] some people don't know some words. So the hearing one is better [illegible] erviews, April 7, 1994). Teresa, because she had not experienced the original version, did not notice that there was a choice for sound. She used it "[j]ust to see if it would explain, like say each fruit [in the picture]" (Student Interviews, May 19, 1994). However, she found it helpful, adding "It explained better; it put it better in my head. When I heard it, I knew it" (Student Interviews, May 19, 1994).

Starting with **Respiratory System,** there were longer and more frequent auditory presentations. As a result, even though students might prefer audio support of graphics in that lesson and in **Atoms & Molecules**, the length and frequency of choice of the auditory presentations had an effect because of the small computer area. All three interviewed students stated that they were bothered by neighboring computers. In

Teresa's words: "I wasn't bothered in earlier [lessons]. This one talked more" (Student Interviews, April 7, 1994). Harry stated that it was hard to listen. Therefore students were asked to use earphones, beginning with the third use (April 14) of **Respiratory System**. Harry and Sam both said that they listened more as a result of using earphones (Student Interviews, April 21, 1994). A comparison of the class mean for audiovisual choices in **Respiratory System** and in **Atoms & Molecules** shows the effect of neighboring computers in the second use of **Respiratory System**. From Table 6, it can be seen that the ratios of the number of auditory to visual choices decreased in the second use of **Respiratory System** but increased markedly with its third use. The decrease can be attributed to interference with speech from neighboring computers. Actually, one student, in her first use of the lesson said, "I'm going to see the definitions because there's too much noise" (Field notes, April 5, 1994). With the donning of earphones for the third use, 16 out of 22 students again returned to an auditory preference while two students maintained a visual preference and four employed both modes. From Table 6 can also be seen a very strong interest in using audio with animations. Of the 11 students reviewing an animation, only the deaf student chose the visual mode.

The ratios in Table 6 do not reflect the preference of the whole class but only of those students using that part of the lesson. In their first use of the two lessons, students were requested to choose all items in the menu at least once. In subsequent uses, students were given freedom of choice. All students did the quiz section and generally more students reviewed the definitions than the animations. In **Respiratory System**, 77% and 84% of the students reviewed the definitions while 66% and 44% of the students went back to the animations in their second and third use of the lesson respectively. Therefore the ratios apply only to those students who wished to view that part of the lesson again.

Table 6. Comparison of number of auditory and visual choices and their relative ratios for definitions and animation sections in **Respiratory System**

	Definitions Section				**Animation Sections**			
Use	n	Audio	Visual	Ratio	n	Audio	Visual	Ratio
Apr. 5	26	103	69	1.49	26	17	11	1.54
Apr. 7	21	65	57	1.14	18	12	10	1.20
Apr. 14	21	82	24	3.41	11	10	1	10.00

Interestingly enough, 12 students from another class used **Respiratory System** on April 8. Being a participant observer, my interest in speech could bias participating students towards audio. However, the 12 students from an alternate grade 5 class used the program without my presence. Of the ten students using the definition section, six students tried both audio and visual definitions and four chose only the audio, giving an audiovisual choice ratio of 5.4 to 1. Of 11 students using the animation section, all but one chose the audio, giving a choice ratio of 10 to 1, the same as the third use of the participating class. The importance of these results is that unbiased students, given freedom of choice, preferred audio explanations on their first exposure to the program. The main difference noted between the use of lessons by students participating in the study and that of other student's casual use was that the former were more inclined to finish lessons. The latter would often quit lessons after a minute or two. The results of April 8 were unique in that several students did finish the lesson. There did not seem to be the same interest and motivation in other students but there was a similar auditory preference.

The similar program, **Atoms & Molecules**, used with earphones during the following two weeks, continues the strong preference for audio. Because of their experience with **Respiratory System**, students knew what to expect in each section concerning audiovisual choices. Of the 26 students using **Atoms & Molecules** the first time, 19 and 15 students had a strong audio preference in the definitions and animation sections respectively while three and five students had a strong visual preference. The remainder were mixed. In its second use, 21 out of 22 students and 16 out of 20 students used audio only in the definition and animation sections respectively.

When students were asked in the final questionnaire if they wished an audio default for audio support of text, 53% stated a preference for having sound on. Interestingly enough, only 53% chose to have sound on for the explanation of pictures. The result might have been different if the wording had been "speech during an animation" that they had experienced and seemed to favor.

From the class response to the lessons and the student interviews, it seems clear that students appreciated the auditory presentations that supported text and explained animations. The ratio of auditory to visual use by those students repeating the animations is overwhelmingly in favor of the auditory. Another indication arising from these two lessons is the necessity of using earphones for audio-intensive computerized lessons.

Length of Speech

Because of the quick increase of file size with the inclusion of digitized speech, it is difficult to have many long auditory presentations. Of the 14 lessons, only four focused on long speeches. **Metric City** and **Metric Town** presented the characteristics of their society while **Respiratory System** and **Atom and Molecules** presented definitions, described animations, or explained a complex graphic. In every case, students had the option of viewing or hearing this information. Their modal preference will be discussed later. Here, the focus is only on their reactions to a longer presentation.

At the time of preparing **Metric City**, the teacher pointed out that the information necessary to do the calculations would be difficult to remember and that it would be good to have it visible on the screen. Although it would be easier to work with, students had to experience a long and complex auditory presentation. We compromised by suggesting to students that they could bring paper and pencil to the computer.

The first time **Metric City** was used, students chose the visual presentations about twice as often as the auditory one. Only one student used the auditory mode alone. The second time, when the simpler **Metric Town** was offered, there was again a strong preference for the visual mode. Harry said, "The full nints were easier to memorize because there was less in the spoken version than in the written. If they were the same, I'd use hearing." He went on to say, "It leaves my memory if I only see it on the board." Sam, on the other hand, said, "Seeing full hints was easier to understand because there was lots. I wrote them on paper to remember." Teresa used both modes for different reasons. "I like hearing the hints when I am having trouble. Seeing allowed me to think about them. I asked to hear the hints because I can understand better when hearing" (Student interviews, March 10, 1994).

Although the definitions in **Respiratory System** and **Atoms & Molecules** were long, there were fewer discrete facts to remember in each definition. Overall, there were more facts to remember in the several terms defined and, although the explanations of the animations and the graphic were longer than the presentations in **Metric City**, they were easier to assimilate, being a voice-over for visible actions. Students were more willing to use the long auditory presentations in **Respiratory System** and **Atoms & Molecules** than in **Metric Town** or **Metric City**. After using **Respiratory System**, Harry and Sam both said the definitions were too long. Sam said, "It told me all the information I needed for the quiz" (Student interviews, April 7, 1994). In the same interview, Teresa thought the definition length was OK, "as long as I get to know it." She also said at another time, "I try to hear and see each time" (Student interviews, April 21, 1994).

In the final questionnaire, students were asked if some auditory presentations were too long or contained too much to remember. Seven students answered yes to the former and eight, to the latter. Lessons cited as containing overlong presentations were: the spelling lessons (3 students), **Respiratory System** (2 students), **Metric City/Town**, and **Food Groups** (1 student each). Those with too much were: **Metric City/Town**,

Respiratory System, Atoms & Molecules, Food Groups (2 students each). The spelling lessons had frequent short auditory presentations controllable by a panel. One of the students who complained about them referred to the directions that were repeated every time unless they changed the setting. This student must not have recognized her options. Students referring to **Food Groups** as difficult must have forgotten that all speech supported visible text. There were few students that focused on the three lessons actually having long or detailed auditory presentations.

From the lesson records and student comments, it would appear that students prefer the visual mode for complex information in order to reflect on it. The length of an auditory presentation was not a deterrent when it was explaining a visual animation. Actually, the information being received in the auditory mode would not interfere with viewing the animation as much as would reading visual information that would compete for attention.

Speaker

Another general aspect of auditory presentations, the speaker, may affect students' desire to listen. In this study, there were only two opportunities to change speakers. In the early part of the study, the grade 5 teacher digitized his voice in a spelling lesson. At the end of the study, the interviewed students were asked to experience the synthesized speech of **KidWorks 2** before answering questions about that type of speech. All other lessons used my digitized voice.

About their experience with a synthesized voice, the interviewed students all agreed that although the voice did not read everything correctly, all three were able to understand it. Teresa said, "The voice is not really like real. It's like a robot, not realistic." Harry said that it was hard to understand, with "too much expression or accent in the words." Teresa saw that it has a use, that it "is good for little kids—one word at a time." All preferred my digitized speech because it's "smoother," (Harry), "higher in pitch," (Sam) and "more understandable" (Teresa, Student Interviews, June 6, 1994).

Having only one lesson with a male digitized voice may not provide sufficient experience for students to form strong preferences about speakers. There would need to be several lessons with various male and female voices to offset the effects of varied clarity of enunciation and expression. This important aspect must be left to future research where it can be the focus of a detailed study rather than merely a part of a broader study.

Frequency of Auditory Directions

As a rule, short textual directions were placed on the screen to permit students to view them whenever necessary. However, in order to test for student preference for this aspect, a control panel was given in the spelling lessons and the lesson began with audio directions rather than visual ones. Although one student complained about having repeated directions in these lessons, students could selectively turn off audio directions at any time.

After students had worked through a spelling lesson once and recognized their options in controlling sound, directions were usually turned off sooner than all other uses. However, students would not need to know the directions after their first use of the lesson so this fact does not indicate their preference for the visual as much as a preference for suppressing repeated or redundant information. The three interviewed students were asked if they would like the directions spoken. Harry said he would not; Sam said he would; Teresa stated that "oral directions would be good, especially in younger grades" (Student Interviews, Feb. 7, 1994).

Besides its presentation frequency, a related consideration is whether students prefer directions in auditory or visual mode. Many lessons placed visual directions for every question at the bottom left of the screen. One lesson, **Place Value**, was designed to present students with a required choice of their preferred mode. Unfortunately, all records of the first student use of **Place Value** were lost. According to the records of later student use of **Place Value**, the ratio of the choice of auditory mode to visual mode was 2.78:1.

To try to discover student preferences about their frequency and use, the year-end questionnaire had two questions about spoken directions. Eighty percent of the students preferred having the frequency of oral directions under their control while the remainder were evenly divided between having directions said every time and having them said only once. Given a choice between speech only, text only or both modes, 69% preferred both modes while 20% desired text only and 11%, speech only. If oral directions were under their control, 65% wished to have sound on as a default.

From these results, it seems that students prefer having both visible and oral directions, and that they prefer to control the frequency of auditory directions.

Positive and Corrective Feedback

This aspect is one that could be included easily in every lesson. As can be seen in Table 5, immediate audio positive and corrective feedback was given in some lessons; others had various combinations of audio and visual feedback. Audio feedback was varied somewhat in two spelling lessons to include non-speech audio as a contrast for student comment. In two lessons, **Respiratory System** and **Atoms & Molecules**, the questions in the adventure section gave immediate visual feedback while the quiz section deferred feedback until all questions had been answered. As only lessons that provided choice have records of student preferences, the records of these will be considered for class preferences.

Five lessons, **Sentence Tutorial** and the four spelling lessons, provided student choice of preferred mode. According to student records for **Sentence Tutorial**, after its initial use when 68% experimented with the two modes, only two students changed the default auditory mode to the visual one. In **Spelling 2** and **Spelling 3**, the students generally permitted the default audio feedback. If they turned it off, they did so at the same time as most other audio. In **Spelling 4** and **Spelling 5**, the default audio feedback included non-speech audio as positive and as corrective feedback respectively. Seventy-six percent of the students kept the audio feedback in the former lesson and 68% in the latter.

Audio feedback was one of the first aspects considered in student interviews. Harry, Sam and Teresa preferred having audio feedback, Harry saying, "It tells me I'm finished, especially in hard questions." Sam added, "Some people might not look down" (Student Interviews, Feb. 3, 1994). In a further interview when they were asked to differentiate between audio positive and audio corrective feedback, Harry and Teresa preferred to have both spoken (Student Interviews, Feb. 17, 1994). While Sam, in that interview, desired the positive spoken and the corrective written, in his next interview he stated that he preferred a choice and wanted to hear the corrective feedback (Student Interviews, Feb. 22, 1994).

In the final questionnaire, students were asked their preferences for auditory or visual mode and for speech or non-speech feedback. Seventy-eight percent and 72% of the students had music as their first choice for positive and corrective feedback respectively while 59% and 54% had speech as their second choice and 69% and 58% placed visual text last. Musical sounds were used in only one lesson, yet were preferred. Generally speech was preferred to a written comment or symbol. As feedback .ost lessons consisted of similar oral responses or of predetermined written words, the high percentage of students choosing music may have been a result of a desire for variety.

From their records and responses, it would seem that students prefer varied auditory feedback (words or sounds), although in the case of corrective feedback, nine out of 26 students placed this use of speech last. If a lesson were to make extensive use of oral corrective feedback, the use of earphones could negate students' possible fear of having others know their errors.

Grade 5 students did not necessarily need immediate feedback. The attraction in the two lessons, **Respiratory System**, and **Atoms & Molecules**, was the quiz section that told students their mark only at the end, without telling them which questions were right and wrong. Students were motivated by the quiz section to study the other parts of the lesson in order to improve their mark the next time.

Hints and Suggestions

Because of storage requirements, hints and suggestions were included in only a few lessons. In only one lesson, **Explorers**, were hints offered in both modes simultaneously, the visual text mode being given and the auditory mode being presented as an option for audio support. Because this option was in the explanation part of the lesson, which could be bypassed by the students, and no records were kept or interviews conducted, there is no information on student response to it. Rather than a study of student preference of presentation mode, this option is an example of audio support of text, which has already been considered.

To study student preferences in this area, **Rounding Off**, **Sentence Tutorial**, **Metric City**, **Metric Town** and the spelling lessons were created to ascertain student modal choices of hints or suggestions. **Rounding Off** presented its rule, **Sentence Tutorial** gave suggestions in the corrective feedback, **Metric City/Town** presented their makeup, and the spelling lessons gave the oral spelling or flashed the word on the screen after the second error on a word.

Students generally used both modes equally in **Rounding Off**. In **Sentence Tutorial**, there was a slight preference for the visual mode. In **Metric City** and **Metric Town**, they used the visual mode twice as often as the auditory one. In the spelling lessons, while only students who had more than two errors would experience the difference between the two, many students set this sound on or off along with the other types.

The automatic change in presentation mode for the hints in the spelling lessons makes the class averages for these lessons un-instructive and indicates the difficulty of testing for this particular aspect. Another factor in student choice besides individual modal preference could be the length and complexity of hints as occurred in **Metric City** and **Metric Town**. Already discussed earlier, the responses of the interviewed students point to individual student preferences, a need to write complex hints down, and a choice differentiated by the immediacy of the need. When Teresa was doing a question, she liked to hear the hints (Student Interviews, March 10, 1994). She could pick out and remember only what she needed while viewing the question on the screen. In a visual mode, she would lose the question screen and would have to remember which part of the rules on which to focus. Yet when she wished to think about the structure of the city or town, she preferred to view it. She could study the relationships at her leisure.

From the lesson responses and interviews, students seem to prefer the visual mode for complex presentations. The presentation should leave the question visible so that both may be studied simultaneously.

In their final questionnaire, 63% of the students preferred the default of sound on for hints and suggestions. However, 88.5% of the students wished all sound default settings to be on at the beginning of the lessons. Rather than referring directly to a preference for audio hints and suggestions, these percentages may indicate that students wish to know what auditory options are available so that they can make choices. While many students thought that the use of sound for hints or suggestions was the most important use in the question relating to different types of use of auditory presentations, as will be discussed later, their recorded responses with the present lessons do not support their statements. This indicates a need for more focused research in this area, using various types of hints and suggestions, with varying lengths and complexity.

Preference for Type of Use

From Table 5, it can be seen that various lessons concentrated on presenting choices to students in the various types of auditory use in computerized lessons. Other lessons offered experiences of the same uses but only those lessons presenting choices can be used to try to determine student preferences. Because these choices have been discussed earlier, a set of lessons with multiple uses of speech and the results of the year-end questionnaire will be examined here.

The spelling lessons were especially designed to have a wide range of uses of speech to encourage students to turn off the types of uses they did not wish. To further encourage students to set their own preferred mode, the fourth and fifth spelling lessons changed the default settings so that students would recognize that these were optional. A similar procedure of changing default settings had been carried out in multiple uses of other lessons to help students realize their options. In the last two lessons, the sound was on for directions and feedback while off for sentences and hints. Only four out of 26 students kept the default settings in one or both of these lessons while all other students varied them. During their use of **Spelling 2** and **Spelling 3**, all students had turned off the defaults at some time during the lessons. These students seemed quite willing to change default settings by this time in the study.

In order to know the required word, students could have the sentence with the missing word read, they could have only the missing word said, or they could guess the word from its context. During the first use of **Spelling 2**, eight out of 27 students asked for the word. The remainder had the sentence read or they guessed the word from its context. In the following three lessons respectively, two out of 25 students, 2 out of 26 students and 10 out of 26 students asked for the words. In **Spelling 3**, students seemed to rely on the context but in **Spelling 4** and **Spelling 5**, 15 out of 26 students and 17 out of 26 students respectively had the sentences read. Even with the default of audio turned off, more of the students preferred the sentences read to having to click on a button to hear the word. The lesson design created a confounding factor in that while the sentence was read automatically, students had to make an extra action to have the word read. Student preference shown in this case might not be so much for audio support of sentence text as for economy of action.

Because of this confounding factor as well as the recognition of the value of students' experiences of speech in computer-based lessons, a year-end questionnaire was developed with a focus on student preference for types of use of digitized speech (see Appendix C). Their first question asked students to rank the six divisions of auditory use given in Table 5. Forty-two percent, 33% and 29% of the students wished audio for hints and suggestions, audio support for graphics or text, and for directions respectively. Twenty-nine percent of the students had audio for positive feedback in second place while 48% of the students had audio for explanations in third place. Thirty-nine percent of the students placed audio for corrective feedback in last place. This would indicate that students appreciated most having audio hints or suggestions and least audio corrective feedback.

Summary of Criteria for Choice of Auditory Presentations

This chapter has reviewed grade 5 student responses to audio choices in their computer lessons, interviews with three students, and responses to a year-end questionnaire. Through this information it can be seen that some or many students prefer:

1) both the choice of the presentation mode and the freedom to change it at will (all students),
2) the availability of both auditory and visual modes for individual needs (the deaf student and one interviewee on his behalf),
3) digitized speech is more intelligible than synthesized speech (all three interviewees, but one liked synthesized speech for young readers),
4) audio support of animations (chosen in 10 to 1 ratio) but the visual option must also be given for individual needs (the deaf student),
5) auditory and visual directions given together with control of the frequency of auditory ones (21 out of 26),
6) the visual mode for complex ir[illegible]on as in **Metric City/Town** (chosen over audio mode in 3 to 1 ratio;
7) that the question be left visible if the visual mode is used for hints and suggestions (one interviewee),
8) that feedback should be varied, including using music (19 out of 26),
9) all feedback can be in the auditory mode as words or sounds and occasionally in the visual mode (22 out of 26 and all interviewees),
10) corrective feedback should be in the visual mode (9 out of 23 and one interviewee), and
11) providing earphones is important for audio-intensive lessons (all interviewees).

An aspect hoped for but not able to be determined in this study was the preference for types of speakers. The next chapter will review in a similar way student responses and interviews to audio choices in the 14 computer lessons created for grade 2.

CHAPTER 6

SEARCHING FOR CRITERIA IN GRADE 2

The study with grade 2 students began with the guidance of the same original audiovisual chart used with the grade 5 students. As the grade 2 lessons were developed, teacher requests and the observation of student interactions caused variations in aspects of auditory presentations in a slightly different manner from those of the grade 5 lessons. There was more stress on audio support of textual material and there were more short auditory presentations, no animations with audio, and fewer hints or suggestions. Table 7 shows the variations considered for each aspect of auditory presentations as well as the lessons incorporating each aspect. Following the same procedure as in chapter 5, student responses to each aspect of Table 7 in turn will be discussed.

Choice

Several lessons had auditory presentations not under student control to accustom students to have speech in computerized lessons. **Fractions** and **Rhymes/Rhymes2** gave auditory directions whenever new ones were required. **Blends 1,2,3**, **Making Change**, and **Rhymes/Rhymes2** had spoken feedback. To vary the type of feedback, **Arithmetic.2** had non-speech audio for all feedback.

As mentioned in the previous chapter, the aspect of choice is important to this study for giving student control, for revealing student preferences and for providing corroborative support for student interview responses. There were three types of choices presented to the students: 1) to see or hear a presentation, 2) to change a presentation mode, and 3) to exercise an option. Unlike the choices presented to the grade 5 students, grade 2 students were never required to choose a presentation mode before continuing in the lesson. This was omitted in order to not impede the flow of the lesson at this level. Choices of an optional presentation mode could be bypassed or a default presentation mode could be used.

The lessons offering the first type of choice were the phonics lessons, **Blends 1**, **Blends 2** and **Blends 3** with a choice of auditory or visual directions. Besides providing an insight into student preferences about choice, these lessons can reveal if students wish to receive a particular type of presentation. In the **Blends 1,2,3** lessons, 33% of the class did not ask for directions in their first use of the lesson and there was minimal use of this feature in the subsequent lessons of this series. Of the 67% who requested directions, the

Table 7. Grade 2 lessons incorporating aspects of auditory presentations

Aspect	Variation 1	Variation 2	Variation 3
Choice	*audio - no choice* Arithmetic.2 Blends 1,2,3 Fractions Making Change Rhymes/Rhymes2	*modal choice* Blends 1,2,3 Fractions Ponds Spelling 2 - 5	*text support* Canada Quiz Fractions Making Change Rhymes/Rhymes2 Spelling 2 - 5
	audio default Ponds A Spelling 2 - 5	*visual default* Ponds B Spelling 4 - 5	*graphics support* Blends 1,2,3
Audiovisual redundancy	*audio and text given* Canada Quiz Making Change Rhymes/Rhymes2 Spelling 2 - 5	*audio and graphics* Blends 1,2,3	
Length of speech	*0 - 5 seconds* All other lessons	*5 - 10 seconds* Ponds	
Speaker	*synthesized speech* KidWorks 2	*digitized speech* All lessons	
Frequency of auditory directions	*every time* Spelling 2 - 5	*visual always - audio requested* Canada Quiz Making Change	*when requested* Blends 1,2,3
	once only Fractions Rhymes/Rhymes2		

(Table 7 continued)

Aspect	Variation 1	Variation 2	Variation 3
Hints/suggestions	*audio or text*		
	Fractions Ponds Spelling 2 - 5		
Feedback (positive - corrective)	*speech - speech*	*visual - visual*	*deferred feedback*
	Blends 1,2,3 Fractions Making Change Rhymes Spelling 2 - 3	Making Change Ponds Spelling 2 - 5	Canada Quiz Spelling 1
	speech - non-speech audio	*non-speech audio - speech*	*non-speech audio - non-speech audio*
	Spelling 4	Spelling 5	Arithmetic.2
Preference for type of use	*directions*	*explanations*	*hints/suggestions*
	Spelling 2 - 5	Ponds	Spelling 2 - 5
	positive feedback	*corrective feedback*	*text support*
	Spelling 2 - 5	Spelling 2 - 5	Spelling 2 - 5

ratio of audio to visual was about 6:5. After a long period of not using the lesson, 50% of the students requested directions. The audio to visual ratio for this repetition was 3:1.

The lessons with the second type of choice were **Fractions** and **Ponds** with their explanations and the spelling lessons with four different uses of auditory presentations. Although the control given in these lessons can reveal students' preferred presentation mode, a caution is needed. If students change a default, it may indicate a preference; if a default is not changed, no conclusion can be drawn, as students could be simply accepting a default unconsciously, not noticing their options. For this reason, some lessons began with an audio default while others began with a visual one.

As the student records for **Fractions** did not clearly indicate student choices, only the records from **Ponds** and the spelling lessons will be considered. Students using **Ponds** began with opposite defaults. When seven students had the audio off in their first use, all turned it on within the first screen. On their second use with the audio on, the seven students left it on. When 14 students started with the audio on in their first use, only two students turned it off during the lesson. On their second use, starting with the audio off, 50% turned it on during the lesson, including one who had turned it off in his first use.

The spelling lessons had four uses of sound, either speech or non-speech audio, with individual controls. In **Spelling 2** and **Spelling 3**, all the audio was on; in **Spelling 4** and **Spelling 5**, the audio was on for directions and feedback and off for sentence reading and hints. One student turned off sound in the first two lessons and then turned it all on except for directions in the last two. Although only one student retained the defaults throughout, 49% of the class kept the defaults for their first three uses. Because part of the lesson design required that students hear the required word, either by having audio on for the sentence reading or by clicking a button for hearing just the required word, the audio to visual ratio for sentences and repeated words was generally high. Other uses would indicate better a student's preference. The audio to visual ratios for a combination of all other choices in the four spelling lessons respectively were 8:1, 9:1, 6:1, and 6:1. From these numbers, it would seem that students preferred auditory presentations when they were given the choice. The tendency of students to accept a default may be a confounding factor for these lessons and has to be taken into consideration.

Lessons offering students the third type of choice were those giving audio support to text or graphics. Would students make use of the options to have audio support? Although the lessons offering audio support for text or graphics will be considered in more detail in another section, it would be good to look at one example.

In the first lesson. **Rhymes/Rhymes2**, audio support could help students hear the rhyming words. Looking at the student records, the class averages for requests for two uses of the lesson were 31.0 and 34.6 respectively, 30% and 41% of the class requesting audio support 50 or more times.

The three students interviewed spoke a few times about the three types of choice. All said that they liked to have choice. In the second interview, to the question if they liked being able to turn off the [feedback] comments, Carrie answered, "I liked being able to turn it off or on." Both Larry and Peter said, "I like having a choice" (Student Interviews, Feb. 22, 1994).

Carrie usually preferred the visual mode. About positive feedback, she said, "I like to have it written. I like reading more than hearing" (Student Interviews, Feb. 7, 1994). Throughout the interviews, she repeated her preference for the visual (Student Interviews, Feb. 22, March 10, May 26, 1994). Peter also preferred the visual mode, saying in the first interview, "It helps me think" (Student Interviews, Feb. 7, Feb. 22, March 10, May 26, 1994). Larry, on the other hand, usually had an auditory preference. At the first interview about positive feedback, he said, "I prefer the oral" (Student Interviews, Feb. 7, 1994). At the second interview, when he referred to both positive and corrective feedback, he stated, "I like everything written so i can read it" (Student Interviews, Feb. 22, 1994). At the third, speaking again about only positive feedback, he returned to his original preference, "I prefer it said to read" (Student Interviews, March 10, 1994). About a mixture of sounds and speech, Larry said, "I like sounds because sounds are funny" (Student Interviews, April 7, 1994). In referring to his retaining the audio defaults in the spelling lessons, he said "I wanted them on because it's boring if there is no sound" (Student Interviews, April 25, 1994). On the whole, Larry preferred the auditory mode while Carrie and Peter preferred the visual.

In the final year-end questionnaire given to the whole class, 76% of the class wished to be able to turn off the sound at any time in the lesson. Another question directly related to choice concerned having a button to hear directions when they wished. Sixty-seven percent of the class preferred having this control as opposed to having directions said once only or said every time. A question referring to mode preference had 71% of the students preferring both speech and written words together, 24% written words, and 9% speech only. Because two other questions on the questionnaire about student preference for presentation mode differentiate between positive and corrective feedback, their responses to these important questions will be considered in that section. From the class response to the lessons and to the questionnaire, students evidently appreciate having control, prefer having both modes simultaneously when possible, and will make use of options presented.

Audiovisual Redundancy

Because grade 2 students are still in the process of learning to read fluently, audio support of text may be useful. One lesson, **Fractions**, gave automatic audio support of the written directions while seven lessons provided audio support of text: **Canada Quiz**, **Making Change**, **Rhymes/Rhymes2** and the spelling lessons. Three lessons also provided audio support of graphics: **Blends 1,2,3**.

In the first lesson, **Canada Quiz** with 10 questions, requests for audio support of text averaged 6.4. In the second lesson, **Making Change**, requests averaged 3.2. This average may be lower because audio support was for a repetition of directions constantly visible and already said once. In the third lesson, **Rhymes/Rhymes2** with 20 questions, class averages of requests for audio support were 31.0 and 34.6 on its two uses respectively. Of the 21 students using the **Blends** lessons, only one did not request audio support of graphics in the first use, one, five, two and one not using it in the next four uses of the lessons respectively. The class averages of requests for audio support were 9.5 and 6.2 for two uses of **Blends 1**, 8.0 and 5.0 for two uses of **Blends 2** and 5.3 for **Blends 3**. The length of the lesson and the difficulty of the words in **Rhymes/Rhymes2** may be a reason for the greater number of requests. From these results, it can be seen that students did make use of available options for audio support.

The interviewed students were not asked directly if they liked having the computer read to them as most audiovisual redundancy occurred only with short directions. Rather they were asked if they would have liked hearing and seeing the words at the same time in **Ponds**, the only lesson with a long auditory explanation. Carrie said, "I would prefer it to just sound or just reading" (Student Interviews, May 26, 1994). In response to this question, Peter said, "Yes. If I make a mistake on a word and don't know it, then the voice would help" (Student Interviews, May 26, 1994). Larry, who said "no" to this question about **Ponds**, showed a desire for audio support of text when he said he preferred **KidWorks 2** to the computerized lessons because "it can read for you" (Student Interviews, May 12, 1994). When he explained why he used the option for audio support of graphics, Peter stated, "I used it when I didn't know what they say [the pictures]" (Student Interviews, March 10, 1994).

In the question relating to audiovisual redundancy in the year-end questionnaire, 19.0% of the class wished speech only; 9.5%, written words only; and 71.5%, the two together. From this response and from their use of the optional audio support, grade 2 students evidently appreciate audio support when text contains difficult words, may not be noticed, or may be incorrectly pronounced by a student, and graphic support when a graphic's name is ambiguous.

Length of Speech

Only the lesson **Ponds** had long auditory presentations in its explanations. The class records show that students who did not start with audio on, turned it on and left it on in their second use of the lesson. Of the students who started with it on, only one turned it off immediately in the first use. In the second use, 50% of these students left the audio off.

The three interviewees had been in the group who started **Ponds** with the audio on. Larry turned it off immediately but used it 45% of the time in his second turn. Carrie used sound 58% of the time in her first use and left it off in the second. Peter retained the defaults each time (on during the first time and off during the second). In their interviews, all three said that they preferred to read the descriptions. Larry, who usually preferred to hear, chose it "to learn more" while Peter said, "It feels better." Given an option to have speech and text, both Carrie and Peter would have preferred having audio support of the text, Peter's reason being for help in knowing the words in the text (Student Interviews, May 26, 1994).

Student preference for the length of auditory presentations could not be determined in this study as there was only the one experience with long presentations. A study focusing on only this aspect, with varying lengths in similar lessons would be needed to determine student preference in length of auditory presentations. What was indicated by student responses is a need for audiovisual redundancy for long auditory presentations in which students have to assimilate and remember material. Seeing the text permits students to study the material while audio support helps those students who have limited word recognition.

Speaker

Because I wished to see if grade 2 students would prefer digitized to synthesized speech, the interviewed students were invited to experience the synthesized speech of **KidWorks 2** before being asked about its intelligibility and their preference concerning the two types of speech. All the computer lessons had used my digitized voice only.

About the clarity of the synthesized voice, all three were able to understand it and only Carrie found a mispronounced word, her brother's name. All three stated that the digitized voice in the lessons was easier to understand. In describing the synthesized voice, Carrie focused on the speed, saying "It slowed down in the first short sentence. The rest was fast but not too fast." Larry called it "weird" while Peter said, "It was confusing. It puts two words together." Both Carrie and Peter preferred digitized speech. Responding with a preference for a type of program rather than a type of speech, Larry stated that he liked this lesson because it "can read for you and with this you can make pictures" (Student Interviews, May 12, 1994).

These student responses show that they accepted synthesized speech well. Although two preferred digitized speech, all three were able to understand the synthesized speech and were not bothered by its lack of inflection or its unnatural delivery. The responses of the three students did not demonstrate an aversion for the synthesized speech. Working during a full day with the class of grade 2 students as they wrote a story in **KidWorks 2**, I heard no students laugh at or comment about the speech capability of this program. This type of speech, while not as understandable, seems to be acceptable to grade 2 students.

Frequency of Auditory Directions

An important aspect of auditory directions is their frequency. Should they be given each time, as were the visual ones; should they be given only once; or should this be under the control of the student? Before the study, I thought students would dislike having them said every time; yet if they are given only once, students might miss them or forget them. I feared that if their use was controlled by the student, many students might ignore them.

The first lesson created had the directions said once only. The next ones, **Blends 1,2,3**, gave students the option of seeing or hearing the directions. On their first use, the students asked me to tell them the directions. Instead of telling them, I pointed out how they were to find the directions. Some students chose a presentation mode for the directions while others ignored the directions altogether, finding out what to do by observing other students or by guessing. The next two lessons, **Canada Quiz** and **Making Change**, presented visual directions and permitted optional audio support. In **Fractions**, audio directions were given once only along with the written text. The option to repeat the directions at any time was given. Finally, in the spelling lessons, the computer gave audio directions every time with the possibility of changing to the visual mode.

As previously discussed, when students had to request directions in the **Blends** lessons, only 67% of them did so on their first use of the lesson. In **Canada Quiz**, 65%

asked an average of 9.1 times for audio support of the text directions, which were also the 10 quiz questions. In **Making Change**, 78% and 50% of the class respectively asked for audio support of the visual text an average of 4 times each during its two uses. In **Fractions**, with text always present and directions said once, 33% of the students requested repeated directions an average of 2 times. In the four spelling lessons, with audio directions always set as a default, 62%, 70%, 84%, 43%, 43% and 46% of the class used the default settings during the six trials with the lessons.

The interviewed students were quite definite in their desire that directions be said a limited number of times. Carrie liked "directions just once;" Larry, "[directions] said just once," and Peter, "directions said twice, not every time" (Student Interviews, Feb. 22, 1994). Their actions, when they used the spelling lessons, did not accord with their statements. Carrie consistently turned off the directions but Larry turned them off only once and Peter left them on throughout.

In the final year-end questionnaire, 90% of the class chose auditory directions as one of the top three choices for audio use. When asked about control, 67% of the students responded that they liked to have a button to hear directions when they wish while 9% wanted them said once and 24% wanted them said every time.

From student responses and interviews, it would seem that students want auditory directions whose frequency they can control. When directions are totally under their control, most students will take the time to find out what they need, especially if they recognize the need. For important directions it may be better to present directions in auditory and visual modes simultaneously for those students who would not take this time.

Hints and Suggestions

Hints and suggestions were included in three grade 2 lessons; in **Fractions** as corrective feedback, in **Ponds** as descriptions of the organisms, and in the spelling lessons as help after two errors. In all three lessons, students had to choose either to use the default mode or to change it.

Because of its lack of student response information for this aspect, **Fractions** cannot be examined. As student choices in **Ponds** have been considered elsewhere because of the length of its descriptions, student response to hints will be described only for the spelling lessons. In the spelling lessons, students were given the option of having the required word flashed on the screen or spelled orally after two errors; the defaults in **Spelling 2** and **Spelling 3** being the latter and in **Spelling 4** and **Spelling 5**, the former.

The difficulties in decoding student records for this aspect in the spelling lessons are that 1) only students making errors would appreciate their choice, and 2) there were four controls. Many children changed the hints control at the same time as others, even though they would not have experienced its effect. Therefore, the choices of three students, Anne, Corry, and Jessie (pseudonyms) who generally achieved scores below 67%, will be examined

In Anne's first use of the spelling lessons, she experimented with the four audio controls. Later, she kept all the audio default settings except for her last use, when she changed to audio on for sentences and kept the visual hints. Corry kept the default setting for his first use. He changed to the visual mode on his second use until he made an error, at which point he changed back to audio. On the next two uses he kept the audio on default. During his last use, in which the audio default was off, he used the visual mode for a few mistakes, audio for two mistakes, and then back to visual. Jessie, on her first four uses of the lesson, used the visual mode. On her fifth use, she experimented with the audio controls and in her two subsequent uses, she requested auditory hints. It can be seen from these three students' choices that there was a preference for the visual mode. Because they were required to type the word, the visual mode might have been chosen for its similarity to the response mode. This may be a confounding factor in searching for their modal preference for general hints or suggestions.

The interviewed students were asked about their auditory or visual preferences for hints or suggestions. Although Larry usually preferred the auditory mode, he said at this interview that he liked "everything written so I can read it." On the other hand, the other two, who usually preferred the visual mode, gave reasons for having oral suggestions. Carrie said that they "could be out loud because they might have hard words if they had chosen to read." Peter said, "help could be said so that I know what I have wrong and can correct it" (Student Interviews, Feb. 22, 1994). Carrie's response shows the need for audio support of difficult text. Peter's response could apply equally well to both visual or auditory modes.

In the year-end questionnaire, only 24% of the class chose hints as a preferred use of auditory presentations. In the class response to the lessons, students generally preferred the visual mode for hints and suggestions. However, the interviewed students were not strongly in favor of one mode. It may be that the scarcity of student experience of a variety of hints and suggestions, the possible confounding factor in the spelling lessons and the length and difficulty of the explanations in **Ponds**, results in students not appreciating this aspect. Further research would need to provide a greater range of experiences for students to determine student preferences in this aspect of auditory presentations.

Positive and Corrective Feedback

Feedback, an auditory presentation easy to include in lessons, can be varied in many ways. Students were able to experience speech for both positive and corrective feedback, visual for both, non-speech audio for one or both types. Some lessons, **Arithmetic.2**, **Blends 1,2,3**, **Fractions**, **Making Change** and Rhymes/**Rhymes2** had required audio feedback; others, **Making Change** and **Ponds**, had required visual feedback; while yet others provided choice. Two lessons, **Canada Quiz** and **Spelling 1**, deferred feedback until all questions were answered, with only the latter listing errors and corrections.

One concern I had was to vary the feedback occasionally, especially after I saw the reactions of students to **Fractions**, in which organ music and some animation were given for students' correct answers on their first try. Students had usually received verbal feedback of a word randomly chosen from a set of four or five. This change surprised and excited them.

As it is only lessons providing choice that can show students' preferences, those lessons will now be examined. The four spelling lessons had a combination of speech, non-speech audio, and text as feedback. **Spelling 4** used a buzz was used for wrong answers and **Spelling 5** used organ music for correct answers. Speech was still used for corrective feedback after two errors. The default for feedback was always set to audio in these lessons but students could change them at will. For the first uses of **Spelling 2** and **Spelling 3**, 12 out of 20 students and 16 out of 19 students respectively did not change the defaults. With **Spelling 4**, some defaults were set as visual to encourage students to use the controls. Students then used the controls, so that in **Spelling 4** and **Spelling 5**, only one student retained the defaults. As for the aspect least used, the students turned off audio for directions more than any other use, so that by **Spelling 5**, it was being used only about half the time.

As the spelling lessons did not provide discriminatory choices between positive and corrective feedback, it is mainly from the interviewed students' opinions and the year-end questionnaire responses that student preferences can be determined. The interviewed students had quite definite opinions about feedback. First of all, they preferred immediate feedback to deferred. In answering if she liked having the computer saying "good" or "correct", Carrie stated, "Yes. I know if I did it right, right away instead of at the end like in spelling" (Student Interviews, March 10, 1994). Carrie preferred written positive feedback to the auditory mode because "I like reading better." She also added that "they should stay on [the screen] a few more seconds" (Student Interviews, Feb. 22, 1994). In referring to corrective feedback, Carrie suggested that "what to do could be out loud because they might have hard words if they had chosen to read" (Student Interviews, Feb. 22, 1994). When it was a comparison between sounds and speech for both positive and corrective feedback, Carrie preferred words "because I didn't know if they were wrong or right but I figured it out" (Student Interviews, April 7, 1994).

Peter, who preferred written positive feedback, differentiated between positive and corrective feedback, saying, "The help could be said so that I know what I have wrong and can correct it" (Student Interviews, Feb. 22, 1994). Another time, he said, "I prefer sounds [to speech], because it makes noise and I know it's a mistake" and "I'd like words for right, sounds for wrong" (Student Interviews, April 7, 1994). Earlier he had said "I would like music all the time for the corrects. I would like it for the wrongs, too" (Student Interviews, Feb. 22, 1994). A sound for a simple wrong answer where help is not needed, need not contradict his earlier statement.

Larry, who usually had an auditory preference, also differentiated between positive and corrective feedback. At the first interview, speaking about positive feedback, he said, "I prefer the oral" (Student Interviews, Feb. 7, 1994). At the second interview, speaking about both positive and corrective feedback, he stated, "I like everything written so I can read it" (Student Interviews, Feb. 22, 1994). At the third interview, speaking about positive feedback again, he said, "I prefer it said to read" (Student Interviews, March 10, 1994). About a mixture of sounds and speech for feedback, he said, "I like sounds because sounds are funny. If there was a combination, I would like sounds for wrongs" (Student Interviews, April 7, 1994). For positive feedback, Larry preferred speech; for corrective, the visual mode or a sound.

In the year-end questionnaire, positive feedback came second as a use for speech while corrective feedback for wrong answers came fifth. When asked if they preferred spoken words, sound, or a visual mode (written words or a check mark) for correct answers, 53% preferred written words or a check mark, 33% wished sound and only 14% wanted spoken words. This response may be a consequence of the lack of variety in the verbal positive feedback in the lessons. All lessons had a random choice out of four or five words. More variety in positive feedback may have resulted in a higher interest. In a similar question for wrong answers, 57% preferred written words or an "X", 33% wished sound and only 10% wanted spoken words.

From this and the interviewed students' responses, it seems clear that students prefer immediate feedback in the visual mode, either written words or a symbol, remaining on the screen until they wish to continue. For variety, an interesting sound can be used for only one or the other, so as not to confuse students with arbitrary sounds for both. For corrective feedback that offers hints or suggestions, the visual mode is preferred for reflection.

Preference for Type of Use

Student responses in the spelling lessons, with their audio control panel to control the auditory or visual presentations of four different uses of speech, were a good beginning in determining student auditory preferences for the various types of use. **Spelling 2** and **Spelling 3** had all audio defaults; **Spelling 4** and **Spelling 5** had audio defaults for directions and feedback only. Students' use of the auditory mode for sentences was high because of the lesson design. Students either could hear the missing word to be spelled or needed to click on the repeat button for the word alone. This was a confounding factor in determining auditory preference as students were placed in the necessity of hearing the missing word, either through hearing the sentence or doing an extra action.

Even with the tendency of 60% and 84% of the students to retain the default settings in the first two spelling lessons respectively, sentence reading and feedback were the uses most favored for auditory presentations. Directions decreased in use. However, since the directions were the same throughout, the decrease of their use does not necessarily reflect a preference for visual directions. A further confounding factor is the combining of feedback for right and wrong answers in one control, although hints, given as corrective feedback, were under a separate control. If the two former feedback types had been separated, there might have been some interesting results.

To determine student preference for auditory presentations for separate feedback types, these three types of feedback were separated in the year-end questionnaire. The student preferences for the six uses for speech were: 90.5% for directions, 66.7% for positive feedback, 47.6% for audio support of text material, 38.1% for the explanation of pictures, 33.3% for corrective feedback, and 23.8% for hints about things to remember. Students were asked to choose three uses for which they would like to have the computer speak. According to their responses, students appreciated most having audio directions and positive feedback. Students appreciated having audio directions when new types of questions were asked. At the same time, few preferred audio hints and audio corrective feedback. Corrective feedback, already discussed, may be better given visually, so students can reflect on it at their own speed.

One finding, related to the frequency and length of auditory presentations, is that in audio-intensive computerized lessons, students do become bothered by nearby computers. Both Carrie and Larry agreed that it bothered them (Student Interviews, April 25, 1994). During the use of the spelling lessons and **Ponds**, students had difficulty focusing on their own computer. One option was to use the visual mode; another, to use earphones. Carrie said that with earphones, "I listened better." Larry stated, "I hear better." Peter replied, "It was helpful so you hear louder" (Student Interviews, April 28, 1994).

Summary of Criteria for Choice of Auditory Presentations

This chapter has reviewed grade 2 student responses to audio choices in their computer lessons, interviews with three students, and responses to a year-end questionnaire. Through this information it can be seen that many students prefer:

1) having a choice of the presentation mode and the freedom to change it at will (16 out of 21 students),
2) digitized to synthesized speech for its intelligibility (two out of three interviewed students),
3) control of the duration of all visual presentations (one interviewed student),
4) repetition of auditory presentations (14 out of 18 students),
5) audio support of text (10 out of 21 stated they wanted it but 19 out of 21 used it when it was available),
6) auditory directions, with control of their frequency (14 out of 21),
7) the visual mode for hints and suggestions (16 out of 21),
8) immediate and varied feedback with less emphasis on a final mark (all, according to observations),
9) positive feedback in the visual mode (11 out of 21),
10) corrective feedback in the visual mode, with possible audio support if it contains difficult words (12 out of 21), and
11) earphones provided for audio-intensive lessons (all, according to observations and interviewees, with the condition by one of the latter that the wire doesn't hamper the use of the keyboard).

Aspects hoped for but not able to be determined in this study were the preferred maximum length of an auditory presentation and the preference for types of speakers.

At the end of the research study, much data had been gathered on the original focus of the study but, because this was a case study, reflection on the whole process was needed in order to answer broader questions. The next chapter will include these reflections as well as the implications of the study and indications of future research needed.

CHAPTER 7

REFLECTIONS ON THE STUDY

This research experience has increased my acceptance of the cognitive learning theory, my appreciation of the information-processing theory and previous research on dual channel perception, my understanding of the case study as a research method, my ability to collaborate with classroom teachers and their students in developing suitable lessons for their subject content needs, and my understanding of students' preferences in various aspects, especially concerning auditory presentations, of computer-based lessons. This chapter will discuss these topics as well as implications for the use of speech in computer-based lessons and for future research in this area.

My Constructivist Philosophy and Research Results

This study was undertaken and designed with a constructivist philosophy, viewing students as subjects in their own learning, able to be self-directed if given a measure of control. Students were given progressively greater control of audiovisual choices, and four lessons in grade 5 permitted student control of lesson flow through menus. Another lesson gave grade 5 students the choice of an easier version. These two types of choices were not given to grade 2 students because of subject matter and time constraints.

When given a menu, students generally reviewed the lesson content before proceeding to the quiz section. Only twice did a poor student do the quiz section first or chose the more difficult version of a lesson. These two observations support the research results that unguided students do not always make the best choices for their learning but the general behavior of the grade 5 students demonstrated their ability to make reasonable choices and take responsibility for their learning. The quiz sections were seen as motivational by these students and they would review the tutorial sections and repeat the quizzes until they were able to achieve a perfect score.

The grade 2 students did not seem to be motivated by good scores. Although they responded enthusiastically when they were named to go to the computer, their goal seemed to be to finish the lesson quickly. Even the better students were not interested in repeating a lesson to achieve a better score.

An important observation noted was the approach to Computer-Based Learning used by some of the poor grade 2 students. They appeared to use trial-and-error methods to find correct answers, clicking on all the possible choices rather than clicking on the audio buttons giving the pronunciation of the graphic or words. In terms of student control of their learning, the poorer grade 2 students seemed neither able to understand the strategies for finding solutions nor able to determine how to take responsibility for their learning. They would have needed individual guidance in problem-solving in the Computer-Based Learning environment before being given the greater personal control permitted by it. How to encourage growth in responsibility in Computer-Based Learning at various grade levels could be an interesting avenue for future research.

The Information-Processing Approach and Research Results

The use of this approach was basic to this study, implying that students have to process all information perceived through the senses. Students generally preferred a mixture of audio and visual information. The mixture permitted the reception of a simpler visual stimulus as demonstrated in the auditory description of an animation. The deaf student, having to read text during the animation, had to deal with greater visual complexity. Students, on a ratio of 10 to 1, chose an auditory description rather than text.

The **Metric City** lesson, with its lists of facts, confirmed research on the visual as being the preferred mode for studying complex information. Students, on a ratio of 3 to 1, chose the visual for memorization of facts. This would also agree with research on learning styles that states that twice as many students prefer the visual to the auditory for learning and that "...the print channel becomes more effective relative to the audio as the difficulty of the materials...increases..." (Hartman, 1961b, p. 237). The audio was chosen for short, simple facts and was preferred when students needed a hint to solve a particular problem or needed directions for an immediate action. The latter had been found as well by Baecker and Buxton (1987) in their research with adults.

Employing dual-channel perception is conducive to deeper processing, according to the information-processing theory. Students did appear to pay close attention to the computer-based lesson, with its visual and auditory stimuli and the requirement of kinesthetic responses. The teachers were happy with the students' apparent learning but it was impossible to determine in this study if deeper processing was occurring. Animations with audio, whose repetition is controlled by the students, add a dimension to the learning that cannot be found in a textbook or a teacher's chalkboard explanation. At the very least, the increased enjoyment and visible attention are by-products valuable in themselves to enable learning.

The observation of students in this study followed the findings of dual-channel research in students being able to receive information simultaneously through visual and auditory stimuli. However, it was also noted that grade 2 students had a strong preference for visual text. They appreciated audio support of the text but wished to be shown the words as well. This may be a result of their stage of literacy, learning new words and developing a more extensive reading vocabulary. Grade 5 students, on the other hand, were more comfortable with their reading skills and appreciated the greater ease of the visual and auditory mixture.

The Research Method

Before the study began, I had proposed a multiple-case study of three students, chosen by the teacher, in each of the two grades. This focus changed to that of a multiple-case study of the two classes. Because all the students in the class used the lessons and provided me with their preferences through computer records of their choices, the knowledge gained came from the class as a whole. I also began to see the class as a unit because each class was marked by its membership in a particular school, by its experience during the study, by its teacher and by the particular character formation given to the class by that teacher. Finally, my role as computer resource teacher provided me with an ideal opportunity to observe all the students in their interaction with the lessons.

I had planned to interview the six students as part of the case study. Because of the change in the case study unit, the purpose of the interviews with the six students also changed. The interviews were now seen as a way of entering into the world of children at that grade level, of viewing the lessons from their perspective and of helping me understand why students in the class made the choices they did. They became an important support for an understanding of children of that age level.

Because all the students in each class were growing in appreciation of, and discrimination in, auditory presentations in the computer lessons, a year-end questionnaire could give good information about their preferences. Therefore, a questionnaire was prepared during the last week of the study. The consequent analysis of the questionnaire gave deeper insights into each student's preferences and, in some cases, strongly influenced the conclusions. The questionnaire became a means to give each student a voice. Although unplanned at the beginning of the research, the giving of a class questionnaire was consonant with the shift to having the class as a unit in the case study.

Teacher Choice of Students

The choice of the three students in each grade was a very important part of the study because much depended on their viewpoints. Because the study began slowly, the students were chosen only at the end of January. This was fortunate as the teachers had observed their classes for almost five months and were able to choose representatives of a wide range of abilities. It was better to wait for teacher knowledge of students before their selection.

The weaker students were not as articulate as the better students but it was good to have them included as a part of the study. The comments they did make were excellent and gave insight into the world of their peers. In a study of this type, the number of students could have been even greater to provide a wide range of students upon which to draw.

Value of the Study to Teachers

The experiences resulting from this study can provide information helpful to teachers. The study shows that students can be good judges of what they need and that our assumptions of their preferences need to be checked.

Because of the time spent observing and interviewing the students, it was possible to enter somewhat into their world. They gave several concrete suggestions for improving the computer-based lessons and evaluated them. This study demonstrated the importance of listening to students, to the way they perceive daily experiences. It also showed the necessity of gaining the confidence of students so that they could express their reactions while sensing that their contributions were received as worthwhile. Children can have a good sense to know what they need.

The study also pointed out the importance of checking assumptions about children's preferences. At the beginning of the study, it was thought that students would not appreciate the use of synthesized speech. This was found to be fallacious. One grade 2 student realized its usefulness for those who would have difficulty in reading. Another pre-supposition was that students would not be able to focus on their own computer's speech in a somewhat noisy environment. Students were able to ignore the sound of other computers until sound-intensive lessons were created, at which point ambient noise became disturbing.

Collaboration with the Teachers

Before beginning the study, the original plan was to have teachers preview the partially finished lesson in order to permit their collaboration in the lesson design. During the course of the study, time constraints often prevented this full collaboration in the design. Instead, we collaborated at the planning and the implementation stages. The teachers always determined the lesson content and, usually, the teaching strategies. I would then bring in the completed lesson for teacher preview and for student use. During the implementation stage, I would help students in their learning at the computer while the teacher worked in the class with the remainder of the class. The teachers, giving me the role of teaching assistant, used me and the computer lessons to extend their influence outside the classroom and to further their learning objectives.

This collaboration grew throughout the study. At the beginning of the year, the grade 5 teacher and I required some time to determine how best to proceed. I tried taking a third of the class at a time to the computers so as to give them more individual attention, but that complicated his teaching schedule. We determined that my taking half of the class at a time would permit him to teach smaller groups and still allow each student to have a computer. On the other hand, the grade 2 teacher preferred that I take a third of the class. Her class consisted of three ability groups each of which contained about seven students. My taking out one group at a time permitted her to give extra time to the groups remaining in the classroom.

Through the collaborative planning of lessons and the teachers' experience in participating in this study, both teachers grew in computer sophistication. In the beginning of the year, the grade 5 teacher, who had worked with me in the pilot study, realized the potential of the computer and could, therefore, suggest interesting and meaningful lessons. The grade 2 teacher had more difficulty in determining what lessons to create. In a final interview, she said, "Now I would have lots more ideas for computer lessons. I know now what lessons would be useful and needed. In the beginning, I hardly knew what the computer could do" (Final teacher interview, October 5, 1994).

Because of the collaborative nature of our implementation of the computer lessons, I wondered if the teachers had found a way of using the computer lessons after the study's end. During the final teacher interview, held a month after the beginning of the new school year, both teachers replied that they had. The grade 5 teacher said, "I sent out a few for remediation with **Place Values** and **Rounding Off**. I plan to use them [the lessons] with half classes; and have half working on assignments inside the classroom while I trouble-shoot both in the classroom and at the computers." The grade 2 teacher said, "I've had all the students at the computers with **Blends 1,2,3**. The first time the computer teacher helped me, but the second time I was alone. There aren't enough computers so I put the students who have difficulty with English with other students" (Final teacher interview, October 5, 1994).

I also wondered if my presence had been intrusive in their class schedules during the year. Both teachers replied that not only had I not been intrusive, but they would have liked to have had me more, "even every day" (Final teacher interview, October 5, 1994). This would not have been possible, given the nature of my research that required a prolonged period of time to create lessons. However, it does indicate an acceptance and appreciation of the potential of the computer in extending the curriculum objectives outside the classroom when the computer is under the control of the teacher. This teacher control was present, not only in my lessons, but also in my teaching students during the year to use various application programs, such as **HyperCard** and **ClarisWorks**, for teacher-determined objectives. Their reply demonstrates a strong desire to continue collaboration in planning computer use to extend their teaching. However, even without extra help, these two teachers now have a foundation to determine how students can benefit best from computer time.

The Value of Collaboration

Although a study that takes on a collaborative nature is difficult to plan because so many aspects are unforeseen, it is very enriching for all the participants. Each person learns from the others and contributes to the process and the final result. Throughout the study, the teachers influenced the study by providing the subject matter, the learning objectives, presentation suggestions, evaluation of the lessons and enthusiasm with student achievement. The teachers and I reflected together during the study and creative ideas were generated through our discussions. Although the collaboration resulted in a set of lessons that answered their needs, it also provided them with experiences that demonstrated how computers could be integrated into the curriculum. This occurred in a special way when the teachers requested that the students learn how to use particular productivity tools; **KidWorks** for wordprocessing in grade 2 and **ClarisWorks** for spreadsheet work in grade 5.

During the study the students and I collaborated in lesson design. Student responses were observed and recorded while the interviewed students' comments were invited to determine student needs and preferences. When possible, a revised version of the lesson was brought the following time for student input. This collaboration provided me with an insight into student preferences at that grade level and it may have provided the students with a sense of being listened to and of having their contributions valued. The student responses at the end of the year showed that they appreciated their experience of computer-based learning integrated into their class subjects. Although they thanked me for creating the lessons, these same lessons had improved a great deal as a result of their collaboration by their evaluations and constructive suggestions.

The value of collaboration with the teachers and students for me was in being allowed to enter into the everyday world of the classroom for almost a full year and in being welcomed as part of the support staff. As part of their world, I experienced their frustrations, joys, difficulties and celebrations. Together we searched, we learned, we developed good tools for future groups to use. The knowledge I garnered was contributed by each teacher and student that collaborated in this study.

Computer Use by the Students in the Two Grades

Although this was not the main focus of the research, I needed to observe student reactions to my lessons in order to maintain their interest and to provide them with meaningful audiovisual choices. Grade 2 students needed much variety in feedback, often preferred the visual mode for practice in reading, and required maximum lesson times of about 20 minutes. Lessons requiring a great deal of typing were very difficult for them. They easily learned how to use the computer and the mouse, how to navigate through the network to find their lessons, and what actions were required in each lesson to continue. They occasionally needed help in getting the directions by clicking on a button and in understanding some subject content. Being given a final score did not seem to have a great impact on them. For grade 2 students, it was better to give instant feedback and to require them to correct an answer before continuing.

Grade 5 students desired extensive, relevant corrective feedback, liked variety in feedback, enjoyed auditory support of animations, and could easily sustain half-hour periods of computer time. They requested help to understand subject content and, occasionally, to set the sound volume. Scores were very important to them. Lessons in which they were assigned different mastery levels and lessons containing quizzes were more challenging and maintained their interest. They did not mind repeating lessons containing quizzes in order to improve their mark.

The grade 2 students tended to retain default settings even when given control until the default settings were varied, emphasizing their possible control. The students did grow in the ability to make choices to reflect their preferences. This was demonstrated in the four spelling lessons in which the default settings were changed in the third and fourth lessons. In the latter in which all other aspects of the lessons were kept constant, only one student retained the defaults. On the other hand, the grade 5 students changed default settings regularly. They had no difficulty in using the computer and were willing to experiment freely. When given freedom in using the menus, student choices were varied but each day they returned to the quiz section and voluntarily studied tutorial sections to improve their quiz scores. Their choices did seem to reflect their preferences.

Students of both grades appreciated the use of colored graphics supporting the concept being learned. As Harry, a grade 5 student, said, "I like pictures that describe the question, that go with the question" (Student Interviews, Feb. 3, 1994). Students of both grades were generally able to work independently of adult supervision. Only when they ran into difficulties or were asked difficult tasks, such as typing words in grade 2 lessons, was adult supervision required to prevent disruptive behavior. Finally, and most importantly, they appreciated our collaboration in using the computer to teach subject matter found in their school subjects. As Carrie, a grade 2 student, said about one of the lessons, "It was good, neat, because it had to do with what we were learning in school" (Student Interviews, May 26, 1994).

Implications for the Use of Speech in Computer Lessons

As the presently available amount of commercial educational software using digitized speech indicates, children enjoy having computers that speak. In this study, students in both grades appreciated having the option of auditory presentations in the lessons but they preferred to be able to control both presentation mode and the frequency of auditory presentations. Modal choice was important not only for students with poor hearing but also for students' individual learning preferences. Thus, default modal settings should be changeable at any time. As well, although the frequency of auditory directions should be under student control, essential directions should be visible at all times.

Default settings, although changeable to allow for individual preferences, should be set to general student preferences. The visual mode was preferred for text in grade 2 to give them practice in reading, for complex information in grade 5, and for corrective feedback in both grades. The auditory mode was preferred for simple directions in both grades, for audio support of difficult text in grade 2, and for audio support of graphics and animation in grade 5.

With sound-intensive lessons, students preferred to have the option to use earphones. Although they themselves might not wish to use them, having other students nearby using earphones cut down on the interference resulting from many computers speaking at once. Schools using sound-intensive computer lessons might want to consider having all students provide personal earphones as part of their school supplies at the beginning of the year. The obtaining of personal earphones might alleviate some parents' fear of the spread of contagious diseases through shared earphones.

In lessons that depended on students hearing words correctly, students asked for multiple repetitions of the words. Because speech is transitory and students may miss an essential word or may not be able to understand a word on its first hearing, they should be able to request the repetition of any auditory presentation beyond a simple "good", "right", or "try again." This requires either a way to redo the current section of the lesson or a button to repeat the current auditory presentation.

Implications for Future Research

This study was done in areas with little previous research, either in the aspect of a researcher's collaboration with children or in the development of criteria for the use of speech in computer-based lessons with children. Its results are offered as a beginning for future research, either in the same vein, or in a deepening of one particular aspect of auditory presentations.

Since this study was exploratory in nature, a replication of it with children of similar grades for a similar or extended period of time may uncover other aspects of auditory presentations not studied, especially by using different guidelines. Even the fact of using different computer lessons with their altered content would give a broader base for conclusions.

There were some aspects of auditory presentations that could not be explored in the depth required to determine student preferences. The first of these is the type of speaker. A complete study on this aspect could focus on presenting similar lessons using several adult speakers as well as several children's voices. Having only one man and one woman speaking would not be sufficient to overcome a preference for an individual's voice. The other aspects that would require individual focus would be the length and complexity of auditory presentations. Lessons would have to be developed for each type of use that lends itself to various lengths and complexity: corrective feedback, directions, hints and suggestions, explanations, and audio support of animations. These two aspects would most likely be interrelated so would have to be studied together. What constitutes complexity in auditory presentations would be an important part of the study as well.

During the study, other avenues for possible future research beckoned. One of these is the effect of using earphones on the preference for having visual corrective feedback. Would students prefer spoken corrective feedback if they were using earphones? A second avenue for possible research is the effect of using earphones on student attention. By closing off competing sounds, are they more attentive to their lessons? This was also a by-product in a study by Sales and Johnston (1993) who found that students with earphones focused their attention on the computer lessons. A third avenue is in the use of digitized sound. A basic assumption in this study was that digitized speech is preferable to synthesized speech, yet students who encountered synthesized speech seemed very accepting of it. Synthesized speech has improved greatly since the research done on its intelligibility by Olson and Wise (1987). It may be worthwhile to investigate the usefulness to the language arts curriculum of a program, such as **KidWorks 2**, which uses synthesized speech.

The conclusions developed during this study depended on many other conditions. For example, the preference of students for visual, corrective feedback could alter depending on the reason for this preference. If the reason was based on the desire not to have others know their mistakes, the use of earphones could affect this preference. Similarly, other student preferences may have been influenced by factors including the subject content and presentation, previous computer experience, individual learning styles, self confidence and willingness to take control. This indicates a need to be cautious about generalizing the conclusions of this study.

Final Comments

The experience of doing this research has been invaluable. I have benefited from meeting the school staff, from my collaboration with the two teachers and from my relationship with the students in the two classes.

The staff welcomed me into their world and permitted me a view of an elementary school where children were esteemed and valued. The two teachers welcomed me into their classrooms as a partner in providing students with learning experiences. They found materials for me to include in the lessons and described the learning objectives they needed. The teachers enthusiastically received the lessons and often expressed their gratitude. Unless there was a strong reason against allowing students to leave at a particular time, they allowed me to take students out of the class during times that were convenient for my schedule. The teachers were also quick to notice improvement in student scores that they felt could be attributed to computer practice.

Lest anyone wonders if teachers would be able to develop similar computer lessons for their own classes, I would like to repeat that an original lesson took 25 to 30 hours of work, beyond the time required to learn to use the authoring program. Classroom teachers do not have sufficient time nor energy during the course of the year to develop suitable lessons. As a computer science teacher, I usually developed one lesson a year in order to maintain a high degree of familiarity with both the programming language and the difficulties students might experience. Creating these lessons would take from 50 to 100 hours. It would not be reasonable to expect teachers to learn to use an authoring program and to develop their own lessons.

The students were generally cooperative and expressed their enthusiasm for the computer lessons. They worked to the best of their ability and occasionally helped other students nearby who were experiencing difficulty or were unsure of subject content matter. Their enthusiasm spread throughout the class, influencing some that could have reacted negatively because of individual difficulties. I believe that the students were honest, making free choices according to individual preferences, and giving me valuable information through these choices.

The six students interviewed were enthusiastic in their participation, answering each question to the best of their ability. Their trusting answers allowed me to see into their world, into their likes and dislikes. I felt they were honest in their opinions of the lessons, indicating the aspects they appreciated and offering suggestions to improve the lessons. Through their answers and observed computer-student interactions, I gained an appreciation for their ability to choose. Thus I could offer more choices in the lessons, trusting that students would make choices conducive to their learning.

The study has helped me understand better the role that computers can play in education when they are integrated into the curriculum and under the control of the teacher. My work during the study became an extension of the teacher's role, offering students learning experiences to support and enhance educational experiences occurring within the classroom.

The initial questions were addressed and answered in various ways. The kinds of auditory presentations appealing to grade 2 and 5 students were determined. Grade 5 students were able to make choices when given control but grade 2 students had to be guided to recognize their freedom. Grade 5 students were given increasing opportunities for control and made full use of them. The interviewed students made useful suggestions for the revision of lessons and the design of future ones. Finally the collaboration with teachers and students helped both groups to grow in sophistication of computer use and an understanding of the important role of computers when integrated into the curriculum.

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APPENDIX A COMPUTER LESSONS CREATED

Table A-1. Computer lessons created for the research

Title(s)	Authoring Program	Subject	Gr	File Size	Type
Arithmetic.2	Authorware	Mathematics	2	698K	Drill & Practice(D&P)
Blends 1, 2, 3	Authorware	Language Arts	2	3,624K	D & P
Canada Quiz	Authorware	Social Studies	2	719K	Quiz
Fractions	Authorware	Mathematics	2	1,196K	D & P / Tutorial
Making Change	Authorware	Mathematics	2	1,121K	D & P / Tutorial
Ponds	Authorware	Science	2	1,395K	Tutorial / D & P
Rhymes / Rhymes2	Authorware	Language Arts	2	2,483K	D & P
Spelling #1	HyperCard	Language Arts	2	119K	Quiz
Spelling #2 - #5	Authorware	Language Arts	2	3,435K	D & P
Atoms & Molecules	Authorware	Science	5	891K	Tutorial / D & P
Division	Authorware	Mathematics	5	1,217K	D & P / Tutorial
Explorers	HyperCard	Social Studies	5	3,908K	Simulation Adventure
Food Groups	Authorware	Health	5	1,035K	Tutorial / Simulation
Metric City	Authorware	Mathematics	5	1,229K	D & P
Metric Town	Authorware	Mathematics	5	452K	D & P
Missionaries	HyperCard	Social Studies	5	684K	Simulation Adventure
Multiplication	Authorware	Mathematics	5	428K	D & P
Place Values	Authorware	Mathematics	5	294K	D & P
Punctuation Tutorial	Authorware	Language Arts	5	797K	D & P / Tutorial
Respiratory System	Authorware	Science	5	1,407K	Tutorial / D & P
Rounding Off	Authorware	Mathematics	5	297K	D & P / Tutorial
Sentence Tutorial	Authorware	Language Arts	5	1,080K	D & P / Tutorial
Spelling 100	HyperCard	Language Arts	5	406K	D & P
TOTAL STORAGE REQUIRED:				30,130K	

Note: The storage on a high-density diskette for Macintosh computers is about 1,410 K.

APPENDIX B STUDENT INTERVIEWS

Figure B-1. Pilot Study, Interview 1

Questions	March 24, 1993 Mathematics Pilot Study - Division Lesson
Pilot Study Interview 1	1. What do you like about the lesson? 2. What could be better? 3. Was the lesson too long? Did you finish? 4. Did you like having the computer talk? Were you bothered by hearing the other computers talking at the same time? 5. Did you know how to turn off the talking? 6. Do you have any comments you would like to make about the lesson?

Ann	Jim	Kitty
1. I like the talking, to know if I got it wrong or not.	1. I like the talking, and the numbers coming down automatically. We can turn off the sound. I like the choice. I like the affirmation of corrects. It's OK that it's not optional.	1. I like working on the computer. It's helpful in showing where to put the numbers.
2. There should be a minus for subtraction so I would know to do that.	2. I'd like the computer to show the carry's.	2. I'd like to write the numbers down. I need to write down the numbers [when I'm multiplying].
3. OK. I didn't finish [45 m. period].	3. It was OK. I finished.	3. I take a long time. It's too long.
4. Yes. I wasn't bothered by all the other computers talking.	4. Yes. I wasn't bothered by the others.	4. I find it useful, instead of talking to myself.
5. No.	5. Yes.	5. No.
6. No.	6. This lesson can help people use multiplication, etc. It should be used by more people.	6. Erase the typing. Erase only the wrong one [wrong part].

Figure B-2. Pilot Study, Interview 2

Questions

Pilot Study Interview 2

April 5, 1993 Mathematics Pilot Study - Division Lesson

1. Was the sound useful?
2. Did you turn the sound back on or not and if you didn't, why not?
3. Were the same directions repeated too often?
4. What would you like to change about the lesson?
5. What was good about the lesson?

Ann	Jim	Kitty
1. I like the sound.	1. The sound was useful. I like the variety of system alerts. It think it would be better to have different voices.	1. It was fun to work with.
2. Not asked. [She had the sound on for directions 77% of the time.]	2. Not asked. [He had the sound on 33% of the time.]	2. I didn't turn the talking on because I knew what to do.
3. The sound repetition is OK and the same voice is OK.	3. I would like the sound repetition to be optional.	3. I liked the repetition because it was like the teacher talking through a lesson. Just like when I was up at the board and the teacher told me what to do.
4. I'd like to erase answers and have the lesson shorter.	4. I'd like to erase a wrong answer immediately.	4. I'd like the computer to show scrapwork. I'd like to erase an answer right away.
5. I like the different levels. It's challenging.	5. I like the different levels. I was able to finish once.	5. I like playing with a computer.

Figure B-3. Grade 5, Interview 1

Questions	Thurs. Feb. 3, 1994 Grade 5 - Punctuation Tutorial
Grade 5 Interview 1	1. Do you like to use the computer for learning? Why? 2. Do you like having pictures? Do you like having coloured pictures? 3. Having "Good", "Correct", "Right" said out loud or written. Which did you prefer? Why? 4. Is there anything you didn't like about the program? 5. Do you have any suggestions to make the program better.

Harry	Sam	Teresa
1. Yes. It's fun. I can make choices and it can make suggestions for answers.	1. Yes. I learn more in math and other subjects. Games help me learn.	1. Yes. It's more interesting. I can learn better by reading than by hearing the teacher. It gets my attention.
2. I like pictures that describe the question, that go with the question. Color preferred.	2. It helps me understand the problem when it goes with it. Color preferred.	2. The pictures help get my attention and gives me ideas. I prefer coloured.
3. I prefer it out loud. It tells me I'm finished, especially in hard questions.	3. I prefer out loud. Some people might not look down.	3. Out loud.
4. It was challenging.	4. No.	4. No.
5. I didn't know when it was going to end.	5. Nothing.	5. The oral has to be clear. I prefer a woman's voice.

Figure B-4. Grade 5, Interview 2

Questions

Grade 5
Interview 2

Monday, Feb. 7, 1994 Grade 5 - Punctuation Tutorial

1. Do you like doing the same program again? Why?
2. Did you improve a lot?
3. Did it help to know that there were six parts and which part you were in?
4. Would you like the directions in the little box said?

Harry	Sam	Teresa
1. Beat your old score - challenge to do better.	1. Learn where to put stuff.	1. Like workirg on computers - more practice and get better.
2. Yes.	2. Think so.	2. Yes. Big.
3. Yes.	3. Yes.	3. Yes.
4. No.	4. Oral. Yes.	4. Oral directions would be good, especially in younger grades.

Figure B-5. Grade 5, Interview 3

Questions — Grade 5, Interview 3

Thursday, Feb. 17, 1994 Grade 5 - Sentence Tutorial

1. What did you think about getting both the rights and wrongs said out loud in this program?
2. Did you notice that you could turn the sound off?
3. Would you prefer one said and the other written so it would be quiet? If so, which?
4. Do you have any comments on the p[illegible]?

Harry	Sam	Teresa
1. Good.	1. It was good.	1. It didn't bother me to let other people hear what I have to do.
2. Yes. I tried it.	2. Yes. I tried it.	2. Yes. I tried it.
3. Yes. Say the wrong so you know you got it wrong. It doesn't bother me to have it said.	3. Yes. I would like the positive out loud and the corrective written.	3. No. It's OK to have both said. I prefer them said.
4. If you do a question wrong, don't say "OK" or "Super" after it's been corrected. It was more challenging than the punctuation because the subject/predicate part was new. It wasn't just review. The expert questions were too easy. The sentences there were easier than earlier.	4. OK.	4. No. With Tim (deaf) in the class we need to be able to see them.

Figure B-6. Grade 5, Interview 4

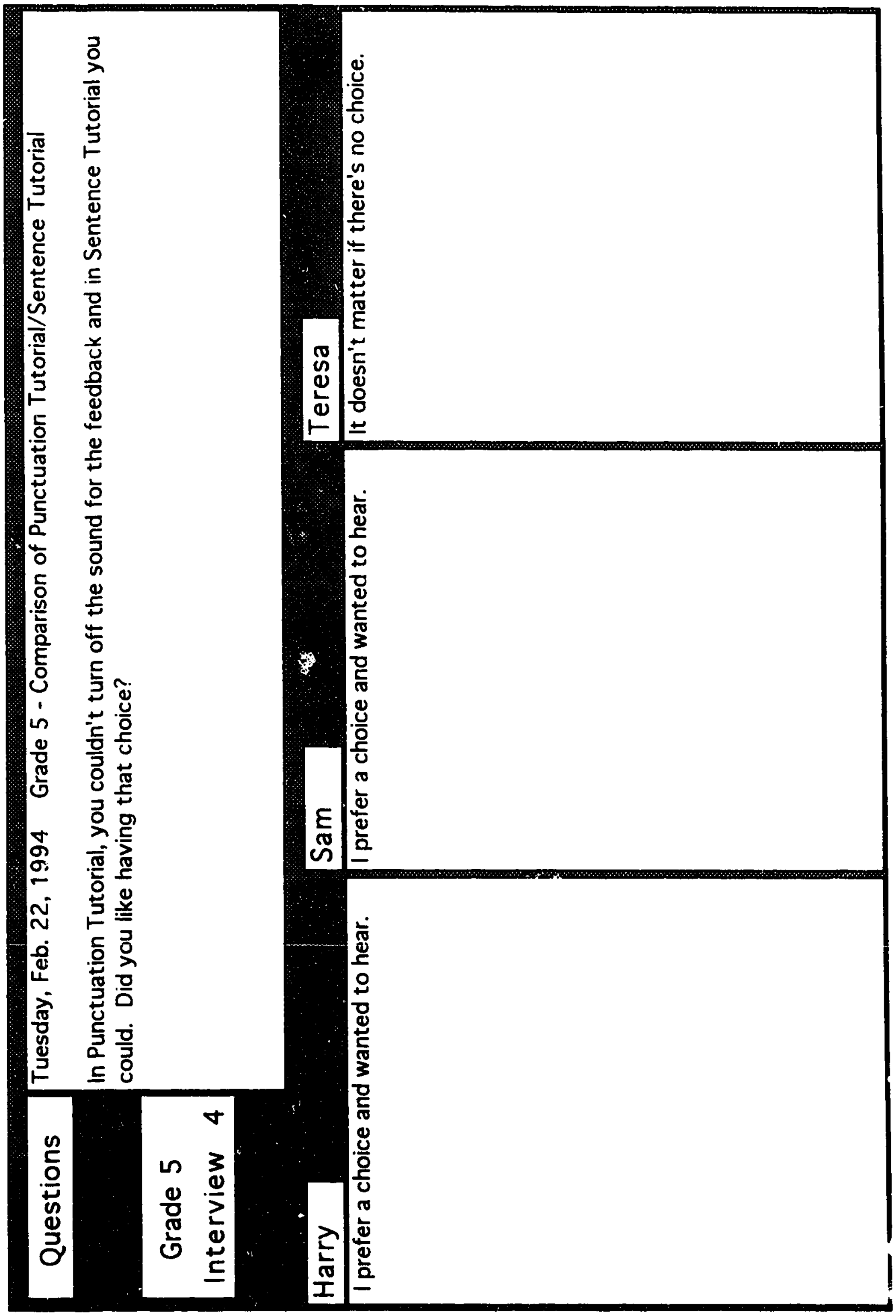

Figure B-7. Grade 5. Interview 5

Questions

Grade 5 Interview 5

Thursday, March 10, 1994 Grade 5 - Metric City/Town

1. In the hints list, which did you use, the audio or visual? Why?
2. When you got an answer wrong twice, you had to ask for audio or visual hints. Which do you ask for? Why?
3. Did you feel you learned something? What?

Harry	Sam	Teresa
1. Hearing the full hints was easier to memorize because there was less in the spoken version than in the written. If they were the same, I'd use hearing.	1. Seeing full hints was easier to understand because there was lots. I wrote them on paper to remember.	1. I like hearing the hints when I am having trouble. Seeing allowed me to think about them.
2. I like to hear the hints because I'm an auditory learner. It leaves my memory if only see it on the board.	2. I asked to hear the hints. I don't know why.	2. I asked to hear the hints because I can understand better when hearing.
3. Yes, I learned how to move the decimals. The last question helped for metric, changing from cm to m.	3. Yes, how many decimal places to put and where to move decimals.	3. Yes, I understand better and I learned how to multiply bigger numbers.
4. Suggestion: add more to the last question, maybe mm and km.	4. No.	4. No.

Figure B-8. Grade 5. Interview 6

Questions

Grade 5 Interview 6

Thursday, April 7, 1994 Grade 5 - Respiratory System

1. Some parts needed to be heard, others to be seen, while some had choices. Did you like that?
2. Were the definitions too long for you?
3. Did you listen to or read the definitions? Why?
4. Did you listen to or see the explanation of the carbon-dioxide cycle? Why?
5. Were you bothered by the sound from the other computers?

Harry	Sam	Teresa
1. Yes.	1. Yes.	1. I liked having choices best.
2. The definitions were too long.	2. Yes, because it told me all the information I needed for the quiz.	2. The definition length was OK, as long as I get to know it.
3. I read because I can remember better.	3. I listened because some people can't read very well. Some people don't know some words. So hearing one is better.	3. I heard the definitions. I tried both, to see which one would help me learn better. It didn't really matter but I prefer hearing. But there should be choices.
4. I read. I don't like listening.	4. I listened for the same reason.	4. I listened. I tried both to see which one is better.
5. Yes. It was really hard to listen because I could hear the other computers talking. I wasn't bothered earlier. [Would earphones help?] Yes. I have two pairs at home.	5. Yes. I was more bothered than in previous ones because others were on the same part.	5. Yes. I wasn't bothered in earlier ones. This one talked more.

Figure B-9. Grade 5, Interview 7

Questions	Thursday, April 14, 1994 Grade 5 - Respiratory System 1. Was listening through the earphones better? How? 2. Did you choose to listen rather than read more than you had last time?
Grade 5 Interview 7	
Harry	1. Others had earphones. I had it quiet because others were listening. 2. I used listening more.
Sam	[at a doctor's appointment.]
Teresa	1. Others had earphones so it was easier for me to hear. 2. I listened more.

Figure B-10. Grade 5, Interview 8

Questions — Grade 5, Interview 8

Thursday, April 21, 1994   Grade 5 - Atoms and Molecules

1. Was this the first time you used earphones?
2. Was it OK? Comfortable?
3. Was it helpful? In what way?
4. Would you like to use them all the time?
5. Did you choose to listen more as a result?

Harry	Sam	Teresa
1. This isn't my first time using earphones.	1. I've used earphones. This isn't my first time.	1. This is my second time using earphones.
2. They were comfortable.	2. I found them comfortable. I didn't mind using them.	2. They are comf
3. They helped to hear better when other computers were talking.	3. It helped because lots of the other computers are saying the same thing.	3. They helped. I got a lot more though I could still hear outside voices from the other computers.
4. I like to use them.	4. I would like to use them all the time.	4. I like to use them. I get more out of it.
5. I listened more.	5. I probably listened more as a result.	5. I try to hear and see each time.

Figure B-11. Grade 5, Interview 9

Questions	Friday, May 19, 1994 Grade 5 - Food Groups
Grade 5 Interview 9	1. Did you have the sound turned on? Why? 2. Did the sound give extra information, more than was on the screen? 3. Was the sound helpful? 4. Do you have any comments on the program?

Harry	Sam	Teresa
1. Yes. It is easier to understand when you have to do work. I prefer it to reading.	1. Yes. With earphones. I just wanted sound.	1. One time each way, because I didn't know I didn't have the sound turned on. Just to see if it would explain, like say each fruit.
2. Yes. It added "is one serving."	2. Yes, I think.	2. No.
3. Yes.	3. Yes.	3. Yes, it explained better, it put it better in my head. When I heard it, I knew it.
4. It was fun.	4. No.	4. It was neat how I could make my own menu and then it would tell me how I did.

Figure B-12. Grade 5, Interview 10

Questions

Grade 5 Interview 10

Monday, June 6, 1994   Grade 5 - Digitized vs synthesized speech

1. Did the computer read everything correctly?
2. Were you able to understand the reading?
3. Which is easier to understand, the speaking in the lessons or this speaking?
4. How would you describe this talking?
5. Which kind of talking do you prefer?

Harry	Sam	Teresa
1. Yes, except for favourite.	1. No. It didn't read the capital words correctly but spelled them out.	1. No.
2. Yes.	2. Yes.	2. Yes. If you really listen you can hear the words wrong, but if you don't, and you read them yourself, you hear them correctly in your mind.
3. Your lessons.	3. Yours are easier to understand.	3. Yours are more understandable. But this is good for little kids - one word at a time.
4. It's deep voiced, hard to understand, too much expression or accent in the words.	4. If it is spelling, you have to put the words together in your mind.	4. The voice is not really like real. It's like a robot, not realistic.
5. Prefer yours because it's nice and smoother.	5. Prefer yours because I'm used to your talking. It's higher in pitch.	5. I prefer natural speech.

Figure B-13. Grade 2, Interview 1

Questions

Grade 2 Interview 1

Thurs. Feb. 7, 1994   Grade 2 - Making Change.

1. Do you like to use the computer for learning? Why?
2. Do you like having pictures? Do you like having coloured pictures?
3. Having "Good", "Correct", "Right" said out loud or written. Which did you prefer? Why?
4. Is there anything you didn't like about the lesson?
5. Do you have any suggestions to make the lesson better.

Carrie	Larry	Peter
1. Yes. It's good for education, fun. I like learning on the computer.	1. Yes. It's fun.	1. Yes. It helps me do stuff better, quicker, makes me smarter.
2. Yes, and I like making pictures. I prefer colour but with black and white, I have to use my own imagination.	2. Yes. I like them in colour.	2. I don't like pictures, just writing.
3. I like to have it written. I like reading more than hearing.	3. Prefer the oral.	3. I like to have it written. It helps me think. [Wrong answers were explained]
4. Some questions were a bit tough. Especially the part teaching us.	4. OK.	4. OK. One part was too hard, where we had to count in our head.
5. I would like to have more questions in part 1.	5. No.	5. Nothing.

Figure B-14. Grade 2, Interview 2

Questions

Grade 2

Interview 2

Tuesday, Feb. 22, 1994 Grade 2 - Fractions

1. Both words like "good", "super",... and the suggestions when you clicked on something wrong were said out loud if you wished. Did you mind having them said out loud?
2. Would you prefer some to be written on the screen rather than said? Which ones?
3. Did you notice that you could repeat the directions? Did you use it? Did you want the directions said more than once?
4. Do you like being able to turn off the comments?
5. Did you like having the music for a change instead of "good", "super", "right"?
6. Would you prefer having sound like that all the time for the corrects? For the wrongs?
7. Do you have any comments about the lesson?

Carrie	Larry	Peter
1. I like them written. I like reading better. They should stay on a few more seconds.	1. I prefer them just written.	1. I left it. I prefer it written so I can read it.
2. Suggestions for what to do could be out loud because they might have hard words if they had chosen to read.	2. I like everything written so I can read it.	2. "Super" could be written but the help could be said so that I know what I have wrong and can correct it.
3. Yes. I like directions just once.	3. Yes, I used it once. I prefer the directions said just once.	3. Yes, I used it. I would like directions said twice, not every time.
4. I liked being able to turn it off or on.	4. I like having a choice.	4. I like having a choice.
5. not asked.	5. not asked.	5. Yes.
6. not asked.	6. not asked.	6. I woul[illegible] music all the time for the corrects. I would like it for the wrongs, too.
7. It was good, fun to do, amusing.	7. It was fun.	7. It is interesting. It makes me smarter.

Figure B-15. Grade 2, Interview 3

Questions	Thursday, March 10, 1994 Grade 2 - Blends-1
Grade 2 Interview 3	1. Did you use the ears by the words or directions in Blends-1? Why/why not? 2. Did you feel you learned something? What? 3. Did you like the computer saying "good", "correct", "right"? 4. What do you think about the spelling lesson? 5. What could make it better?

Carrie	Larry	Peter
1. I like to see the direction. I like reading better than hearing.	1. Yes.	1. I liked it by the words. I used it when I didn't know what they [pictures] say. I knew the directions.
2. Yes. Sometimes I forget blends. It's good to review, learn them better.	2. No. I knew the blends.	2. Yes, what things start with and how to spell the first two letters.
3. Yes. I know if I did it right, right away instead of at the end, like in spelling.	3. Yes, I like the sound because it's funny. I prefer it said to read.	3. Yes. It helps me know it's right. I like it written. I can read it. I prefer to read.
4. It was good. I liked it. It was hard to hear the words, like sit-set. I got it wrong because I couldn't hear right.	4. It was fun.	4. It was hard to listen to the words because they were quiet.
5. Say it more clearly or draw a picture.	5. Nothing.	5. Make the words louder.

Grade 2
Interview 4

1. What did you think of the sounds for right and wrong answers?
2. Which do you prefer, sound or speech?
3. If you had to have a combination of sounds for one and spoken words for the other in correct and wrong answers, how would you like the combination?

Carrie	Larry	Peter
1. I liked them. 2. I like words better because I didn't know if they were wrong or right but I figured it out. 3. If there was a combination, I would like sounds for wrongs.	1. I liked them. 2. I like sounds because sounds are funny. 3. If there was a combination, I would like sounds for wrongs.	1. It was good. 2. I prefer sounds, because it makes noise and I know it's a mistake. 3. If combination, I'd like words for right, sounds for wrong.

Figure B-17. Grade 2, Interview 5

Questions	Monday, April 25, 1994 Grade 2 - Spelling #2
Grade 2 Interview 5	1. Were you bothered by all the computers speaking? 2. Did you turn off some of the sound? Which? 3. Did you leave some on? Which? Why? 4. Is there anything else you would like to say about the lesson? 5. Is there anything you'd like to say about the rhymes lesson?

Carrie	Larry	Peter
1. Yes.	1. A little bothered.	1. Not bothered [He was near a silent computer in a set of two.]
2. I turned off the directions only. Once I turned off the answers so I could see how it would be shown.	2. No.	2. No.
3. Yes. The sentence, to tell me which word to put down in the sentence.	3. I wanted them on because it's boring if there is no sound.	3. Didn't need help.
4. I like it, how it helped with spelling words. It's a good lesson.	4. No.	4. No.
5. It's good. I enjoyed it. I like how it's set up.	5. No.	5. It's fun.

Figure B-18. Grade 2, Interview 6

Questions

Grade 2 Interview 6

Thursday, April 28, 1994 Grade 2 - Spelling #3

1. Was this the first time you used earphones?
2. Was it OK? Comfortable?
3. Was it helpful? In what way?
4. Would you like to use them all the time?
5. Did you choose to listen more as a result?

Carrie	Larry	Peter
1. This is the first time on the computer.	1. First time on computer. I've used them at home.	1. First tir[illegible]nputer, not first time at home.
2. Yes.	2. OK and comfortable.	2. OK and comfortable.
3. I don't get confused with other people's work. I liked it.	3. Yes, I hear better.	3. It was helpful so you hear louder.
4. Yes, but not if it interferes with typing.	4. Yes.	4. Yes, I would like them all the time.
5. I listened better.	5. Yes.	5. Yes.

Figure B-19. Grade 2, Interview 7

Questions Grade 2 Interview 7	Tuesday, May 10, 1994 Grade 2 - Spelling #4 and #5 1. In one lesson the computer buzzed when you made a spelling mistake but said "good", "correct", etc. when you got it right. In the other lesson, the computer said, "No, try again" for mistakes and made a sound for correct. Before that the computer had used words for both correct and mistakes. Which do you prefer? Why? 2. Which of the sounds of the last two lessons do you prefer? Why?	
Carrie	**Larry**	**Peter**
1. I liked the last two lessons with the change because it was different from the others. 2. I prefer the last one because I prefer the sound of right better than the sound of buzz for wrongs.	1. I prefer the last lesson because it makes a funny noise when it is right. But I don't prefer noise to having it said. I prefer words for the wrongs. 2. [answered in number 1.]	1. I preferred spelling 5 because I liked the sound of organ music. 2. I preferred that sound.

Figure B-20. Grade 2, Interview 8

Questions	Thursday, May 12, 1994 Grade 2 - Digitized vs Synthesized speech
Grade 2 Interview 8	1. Did the computer read everything correctly? 2. Were you able to understand the reading? 3. Which is easier to understand, the speaking in the lessons or this speaking? 4. How would you describe this talking? 5. Which kind of talking do you prefer?

Carrie	Larry	Peter
1. It read my name correctly but not my brother's.	1. Yes.	1. It read everything correctly.
2. Yes, I was.	2. Yes.	2. Yes.
3. The ones in the spelling and other lessons.	3. The spelling ones.	3. The ones in the lessons.
4. It slowed down in the first short sentence. The rest was fast but not too fast.	4. It's weird.	4. It was confusing. It puts two words together.
5. I preferred the spelling ones. The voice sounded better and the questions sounded more like a question.	5. I prefer this one because it can read for you and with this you can make pictures.	5. I like it better in the lessons. It's better because it doesn't put words together.

Figure B-21. Grade 2, Interview 9

Questions

Grade 2 Interview 9

Thursday, May 26, 1994 Grade 2 - Ponds

1. Did you prefer to hear the explanations or read them?
2. If read, were there some words that you didn't understand?
3. Would you have liked to have the words to see and hear at the same time?
4. Do you have any comments on the lesson?

Carrie	Larry	Peter
1. Read. I liked it better.	1. I prefer to read, to learn more.	1. Read. It feels better.
2. No.	2. No.	2. No.
3. Yes. I would prefer it to just sound or just reading.	3. No.	3. Yes. If I make a mistake on a word and don't know it, then the voice would help.
4. It was good, neat because it had to do with what we were learning in school.	4. No.	4. It was fun.

APPENDIX C

YEAR-END QUESTIONNAIRES

June 6, 1994 Grade 5 Questionnaire Name:________________

(Where there are blanks, put 1, 2, 3, etc. for preferences with 1 best)

Now that you have experienced having speech in computer lessons...

1. Which do you think are the most important ways of using sound instead of words on the screen?

   ______a) for directions
   ______b) for explanation of pictures
   ______c) for wrong answers
   ______d) for right answers
   ______e) for suggestions or hints for things you have to remember
   ______f) for reading what is written on the screen

2. In explanations or directions, do you prefer

   ______a) speech only
   ______b) written words on the screen only
   ______c) both - speech with the written words

3. If directions are said, do you prefer having them said

   ______a) once
   ______b) every time
   ______c) only when you wish, with a button to press to hear the directions

4. For right answers, do you prefer

   ______a) speech
   ______b) sound, like music
   ______c) written words on the screen or a check mark.

5. For wrong answers, do you prefer

   ______a) speech
   ______b) sound, like music
   ______c) written words on the screen or an X mark.

6. Did any of the programs have talking that was too long? If so, which? *(Circle)*

   yes no ____

7. Did any of the programs have too much to remember in the talking? If so, which? *(Circle)*

   yes no ____

8. Do you prefer to have the sound <u>on</u> when you start and then turn it off if you don't want it or do you prefer to have the sound off and turn it on if you wish? *(Circle)*

   on off at the beginning

9. Do you want to be 'e to turn sound on (or off) for some uses and leave others off (or on)? *(Circle)*

   yes   no

10. Do you want to be able to control the sound only at the beginning or any time in the program? *(Circle)*

   only at beginning   any time

11. For which of the following would you like to have sound on and for which ones off? *(Circle)*

   a) directions..on..........off
   b) explanations of pictures ....on..........off
   c) wrong answers ....on..........off
   d) right answers ....on..........off
   e) suggstions or hints - things to remember...........on..........off
   f) reading what is on the screen.......................on..........off

Table C-1. Compilation and summary of Question 1, Grade 5 Questionnaire

Name	Directions	Explanations	Wrong Answers	Right Answers	Suggestions or hints	Text support
Adela	3	2	6	5	1	4
Barbara		3		2	1	
Cindy	5	4	1	3	2	6
David	5	6	4	2	1	3
Elizabeth	1				1	1
Fay	4	3	6	5	2	1
George		1			2	
Gina	4	3	6	5	1	2
Gus	6	3	5	4	2	1
Harry	4	2	6	1	5	3
Tim (deaf)	5	6	3	2	4	1
Jeanette	2	3	4	5	6	1
Karl	1	3	5	2	4	6
Lori	5	4	3	2	1	1
Marianne	4	3	5	6	1	2
Mark	4	3	6	2	1	5
Ned	1	1	6	1	1	1
Orson	5	2	6	4	1	3
Paula	1	3	5	4	2	3
Peter	1	3	5	4	2	6
Rose	1	4	5	6	3	2
Russ	4	3	2	1	6	5
Sam	3	1	4	2	5	4
Sandra	3	4	6	5	1	1
Teresa	1	6	5	4	2	3
Vera	4	3	6	1	2	5
Entries	24	25	23	24	26	24

	Directions	Explanations	Wrong Answers	Right Answers	Suggestions or hints	Text support
Ones	7	3	1	4	11	8
Twos	1	3	1	7	8	3
Threes	3	12	2	1	1	5
Fours	7	4	3	5	2	2
Fives	5	0	7	5	2	3
Sixes	1	3	9	2	2	3

Table C-2. Compilation and summary of Questions 2-3, Grade 5 Questionnaire

Name	Question 2 (Explanations/Directions)			Question 3 (Directions)		
	Spoken	Written	Both	Once	Every time	Button to hear
Adela	3	2	1	2	1	3
Barbara	3	2	1	2	3	1
Cindy	2	1	3	2	3	1
David	1	3	2	3	2	1
Elizabeth			1	1		1
Fay	3	2	1	3	2	1
George			1			1
Gina	3	1	2	2	3	1
Gus			1			1
Harry	1	3	2	1	3	2
Tim (deaf)	3	1	2	2	3	1
Jeanette	3	2	1	3	2	1
Karl	2	3	1	2	3	1
Lori	3	2	1	3	2	1
Marianne	2	3	1	2	3	1
Mark	3	1	2	2	3	1
Ned	3	2	1	3	2	1
Orson	2	3	1	3	1	2
Paula			1			1
Peter	2	3	1	2	3	1
Rose	3	1	2	1	3	2
Russ	2	3	1	2	3	1
Sam	3	2	1	2	3	1
Sandra	1	2	1	3	2	1
Teresa	3	2	1	3	1	2
Vera	2	1	3	2	3	1
Entries	22	22	26	23	22	26

	Spoken	Written	Both	Once	Every time	Button to hear
Ones	3	6	18	3	3	21
Twos	7	9	6	12	6	4
Threes	12	7	2	8	13	1

Table C-3. Compilation and summary of Questions 4-5. Grade 5 Questionnaire

	Question 4 (Right answers)			Question 5 (Wrong answers)		
Name	Spoken	Music	Written	Spoken	Music	Written
Adela	2	1	3	2	1	3
Barbara	2	1	3	3	1	2
Cindy	2	1	3	2	1	3
David	2	1	3	2	1	3
Elizabeth		1		1		
Fay	2	1	3	2	1	3
George		1			1	
Gina	3	1	2	3	1	2
Gus		1			1	
Harry	2	1	3	2	1	3
Tim (deaf)	3	2	1	3	2	1
Jeanette	3	2	1	3	2	1
Karl	2	1	3	1	2	3
Lori	2	1	3	2	1	3
Marianne	2	1	3	2	1	3
Mark	2	1	3	1	3	2
Ned	3	2	1	2	1	3
Orson	1	2	3	3	1	2
Paula		1		1		
Peter	2	1	3	2	1	3
Rose	2	1	3	2	1	3
Russ	2	1	3	2	1	3
Sam	1	3	2	2	1	3
Sandra	1	2	3	1	2	3
Teresa	3	2	1	3	2	1
Vera	3	1	2	2	3	1
Entries	22	26	22	24	24	22

	Spoken	Music	Written	Spoken	Music	Written
Ones	3	19	4	5	17	4
Twos	13	6	3	13	5	4
Threes	6	1	15	6	2	14

Table C-4. Compilation and summary of Questions 6-9, Grade 5 Questionnaire

	Question 6 (Too long?)		Question 7 (Too much)		Question 8 (Default on)		Question 9 (Distinct use)	
Name	yes	no	yes	no	on	off	yes	no
Adela		1		1	1			1
Barbara		1		1	1		1	
Cindy		1	1		1		1	
David	1		1		1		1	
Elizabeth		1		1	1		1	
Fay	1			1	1		1	
George		1		1	1		1	
Gina		1		1	1		1	
Gus		1	1			1	1	
Harry		1	1			1	1	
Tim (deaf)		1		1		1		1
Jeanette		1		1	1		1	
Karl	1			1	1		1	
Lori	1		1		1		1	
Marianne		1		1	1		1	
Mark		1		1	1		1	
Ned		1		1	1			1
Orson		1		1	1		1	
Paula		1		1	1		1	
Peter	1			1	1		1	
Rose		1		1	1		1	
Russ		1	1		1		1	
Sam		1		1	1		1	
Sandra		1	1		1		1	
Teresa	1		1		1		1	
Vera	1			1	1		1	
Totals	7	19	8	18	23	3	23	3

Table C-5. Compilation and summary of Questions 10-11, Grade 5 Questionnaire

Name	Question 10 (Control?)		Question 11 (Sound on)					
	At beginnng	Any time	Directions	Explana-tions	Wrong answers	Right answers	Suggestions or hints	Text support
Adela		1	1	0	1	1	1	1
Barbara		1	1	0	0	0	1	0
Cindy		1	0	1	1	1	1	0
David		1	1	1	1	1	1	1
Elizabeth		1	1	1	1	1	0	1
Fay		1	0	0	1	1	1	1
George		1	0	1	1	1	1	1
Gina		1	1	0	1	1	0	0
Gus		1	1	1	1	1	0	0
Harry		1	1	0	1	1	0	0
Tim (deaf)		1	0	0	0	0	0	1
Jeanette		1	1	1	0	0	1	1
Karl		1		1	1	1	0	0
Lori		1	1	0	1	1	1	1
Marianne		1	0	1	1	1	1	1
Mark		1	1	0	0	1	1	1
Ned		1	1	1	0	1	1	0
Orson		1	1	0	0	1	1	1
Paula		1	1	1	0	1	0	0
Peter		1	1	1	1	1	0	0
Rose		1	1	0	1	1	0	0
Russ		1	0	0	0	0	1	0
Sam		1	0	1	1	1	1	1
Sandra		1	1	1	1	1	1	1
Teresa		1	1	1	1	1	1	1
Vera		1	0	0	1	1	1	0
Totals	0	26	17	14	18	22	17	14

June 6, 1994 Grade 2 Questionnaire Name:________________________

Put a circle around the ones you choose.

1. For which uses do you like having the computer talk? (Choose 3)

   directions
   explanation of pictures
   wrong answers
   right answers
   hints about things to remember
   reading what is written on the screen

2. Which do you like? (Choose 1)

   speech only
   written words only
   both -speech and written words

3. Which do you like? (Choose 1)

   directions said once
   directions said all the time
   a button to hear directions when you want

4. For right answers, which do you like? (Choose 1)

   spoken words, like "good"
   sound, like music
   written words or a √

5. For wrong answers, which do you like? (Choose 1)

   spoken words, like "no, try again"
   sound, like music
   written words or an **X**

6. Do you want to have the sound on or off when you start? (Choose 1)

   on off

7 Do you want to be able to turn the sound on or off any time in the program?

   only at beginning any time

Table C-6. Compilation and summary of Question 1, Grade 2 Questionnaire

Name	Directions	Explanations	Wrong Answers	Right Answers	Suggestions or hints	Text support
Arlene	1		1	1		
Anne	1		1		1	
Cameron	1	1	1			
Corry	1			1		1
Dawn		1		1		1
Ernest	1			1		1
Francis	1			1		1
Jessie	1			1		1
Inez	1	1			1	
Gina	1				1	1
Lorne	1			1		1
Carrie			1	1	1	
Morna	1		1	1		
Nellie	1	1		1		
Larry	1	1		1		
Patricia	1	1		1		
Peter	1		1			1
Rose	1		1	1		
Samuel	1			1	1	
Tom	1	1				1
Wayne	1	1				1
Totals	19	8	7	14	5	10

Table C-7. Compilation and summary of Questions 2-3, Grade 2 Questionnaire

	Question 2 (Spoken vs Written)			Question 3 (Directions)		
Name	Spoken	Written	Both	Once	Every time	Button to hear
Arlene			1			1
Anna			1		1	
Cameron	1			1		
Corry			1			1
Dawn			1			1
Ernest			1	1		
Francis			1			1
Jessie	1					1
Inez	1					1
Gina		1			1	
Lorne			1		1	
Carrie		1				1
Morna	1					1
Nellie			1			1
Larry			1			1
Patricia			1			1
Peter			1			1
Rose			1			1
Samuel			1		1	
Tom			1		1	
Wayne			1			1
Totals	4	2	15	2	5	14

Table C-8. Compilation and summary of Questions 4-5, Grade 2 Questionnaire

	Question 4 (Right answers)			Question 5 (Wrong answers)		
Name	Spoken	Music	Written	Spoken	Music	Written
Arlene			1			1
Anna			1			1
Cameron			1			1
Corry			1		1	
Dawn		1			1	
Ernest			1			1
Francis			1			1
Jessie		1			1	
Inez		1			1	
Gina	1				1	
Lorne		1			1	
Carrie			1			1
Morna			1			1
Nellie			1	1		
Larry		1				1
Patricia		1		1		
Peter	1					1
Rose			1			1
Samuel			1			1
Tom		1			1	
Wayne	1					1
Totals	3	7	11	2	7	12

Table C-9. Compilation and summary of Questions 6-7, Grade 2 Questionnaire

	Question 6 (Sound default on)		Question 7 (Control)	
Name	On	Off	Only at beginning	Any time
Arlene	1			1
Anna	1			1
Cameron		1	1	
Corry	1			1
Dawn	1			1
Ernest	1			1
Francis	1			1
Jessie	1			1
Inez	1		1	
Gina	1		1	
Lorne	1			1
Carrie	1			1
Morna	1			1
Nellie	1			1
Larry	1			1
Patricia	1			1
Peter	1			1
Rose	1			1
Samuel		1		1
Tom	1		1	
Wayne	1		1	
Totals	19	2	5	16

APPENDIX D

CLASS SUMMARIES OF STUDENT RECORDS

Table D-1. **Atoms & Molecules** results for Grade 5, April 18, 1994

Name	Time (min.)	Score	Definitions Section Audio	Definitions Section Visual	Animation Sections Audio	Animation Sections Visual
Aaron	15	44			2	0
Adela						
Barbara	21	55	4	0	2	2
Cindy	17	45	4	0	2	0
David	14	62	4	0	2	0
Elizabeth	15	69	5	0	3	0
Fay	9	68	7	3	0	2
George	9	71	7	1	2	0
Gina	14	74	2	3	1	1
Gus	14	71	10	1	2	0
Harry	10	[illegible]	3	0	2	0
Tim (deaf)	14	[illegible]	0	8	0	4
Jeanette	24	47	4	0	2	0
Karl	14	[illegible]	4	1	1	0
Lori	18		8	0	3	0
Marianne	12	58	1	3	0	2
Mark	13	55	5	0	2	2
Ned	17	46	4	0	2	2
Orson	14	62	4	0	1	0
Phyllis	19	66	5	0	2	0
Paula	8	61	1	4	0	1
Peter						
Rose	15	68	4	4	0	2
Russ	19	45	4	0	2	0
Sam	8	71	4	0	1	1
Sandra	13	83	3	2	3	0
Teresa	14	58	4	0	3	0
Vera	19	61	4	0	2	2
Mean	14.6	61.0	4.0	1.2	1.6	0.8
SD	3.98	11.58	2.16	1.98	1.00	1.11
n = 26						
AV choices			25	25	26	26
AV totals			105	30	42	21

Table D-2. **Atoms & Molecules** results for Grade 5. April 21, 1994

Name	Time	Score	Definitions		Animations	
			Audio	Visual	Audio	Visual
Aaron	11	66	2	0	1	0
Adela	16	40	4	0	3	0
Barbara	24	60	4	0	3	0
Cindy	8	58			2	0
David	16	55	6	0	2	0
Elizabeth	9	66	4	0	2	0
Fay	8	80	4	0		
George	13	84	4	0	3	0
Gina	5	83				
Gus	11	74	3	0		
Harry	16	78	1	0		
Tim (deaf)	11	76	0	8	0	2
Jeanette	17	52	4	0	2	0
Karl	12	62	4	0	0	1
Lori	22	85	5	0	2	0
Marianne	5	45				
Mark	8	62	4	0	2	0
Ned	9	71	4	0	2	0
Orson	12	45	4	0	2	0
Phyllis	9	90				
Paula	3	76				
Peter	17	68	8	0	3	0
Rose	11	77			2	2
Russ	15	80	2	0	3	0
Sam	14	50	4	0	1	1
Sandra	15	71	4	0	2	0
Teresa	13	76	7	0	2	0
Vera	14	78	5	0		
Mean	12.3	68.1	3.95	0.36	1.95	0.3
SD	4.81	13.5	1.76	1.71	0.89	0.66
n = 28						
AV choices			22	22	20	20
AV totals			87	8	39	6

Table D-3. **Atoms & Molecules** results for Grade 5, April 28, 1994

			Definitions Section		Animation Sections	
Name	Time	Score	Audio	Visual	Audio	Visual
Aaron	3	66			1	0
Adela	4	52				
Barbara	2	58				
Cindy	6	71			2	1
David	9	62			2	0
Elizabeth	7	66	4	0		
Fay	4	90	0	4	0	2
George	8	76	4	0	2	1
Gina	3	76				
Gus	1	83				
Harry						
Tim (deaf)	2	90	0	8	0	2
Jeanette	15	57	4	0	3	0
Karl	8	52	4	0	2	0
Lori	7	90	4	0	2	0
Marianne	3	62				
Mark	4	66				
Ned	5	76				
Orson						
Phyllis	13	88	4	0		
Paula	1	66				
Peter	9	71	5	1	2	0
Rose	4	76				
Russ	5	90				
Sam						
Sandra	5	75			2	0
Teresa	6	71				
Vera	3	83				
Mean	5.48	72.5	3.22	1.44	1.64	0.55
SD	3.47	12	1.86	2.79	0.92	0.82
n = 25						
AV choices			9	9	11	11
AV totals			29	13	18	6

Table D-4. **Food Groups** results for Grade 5, May 16, 1994

Name	Time	Score	Audio	Report
Aaron	9	40	1	VF too low
Adela	13	40	20	GP too low, MA too high
Barbara	16	60	20	MA too high
Cindy	15	40	20	GP too low, VF too low, MA too high
David	20	40	17	MP too low, MA too high
Elizabeth	13	40	20	GP too low, VF too low
Fay	14	40	20	GP too low, VF too low, MA too high
George	15	40	20	GP too low, VF too low, Meat and Alt. too high
Gina	12	40	20	GP too low
Gus	15	40	20	VF too low, MP too low, MA too high
Harry	16	60	18	MA too high
Tim (deaf)	4	40	1	VF too low, MA too high
Jeanette	25	40	20	VF too low, MP too low, MA too high
Karl	16	40	20	GP too low, MA too high
Lori	22	40	20	GP, MP too low, MA too high
Marianne	18	40	20	GP too low, MA too high
Mark	13	90	20	Excellent choices. You have a healthy diet.
Ned	24	40	20	GP too low, VF too low, MA too high
Orson				
Phyllis	18	40	17	VF too low, MP too low, MA too high
Paula	21	40	20	VF too low, MP, Meat too low, Sugar, Fat too high
Peter	18	40	20	VF too low, MA too high, Fat too high
Rose	14	40	20	MP too low, MA too high
Russ	15	40	20	VF too low, MP too low, MA too high, Sugar, Fat too high
Sam	15	90	20	Excellent choices. You have a healthy diet.
Sandra	16	40	20	VF too low, MA too high
Teresa				
Vera	15	40	20	VF too low, MP too low, MA too high
Mean	15.9	45.5	18.2	
SD	4.4	14.2	5.2	
n = 26				

Note: Vegetables and Fruits (VF)
Meat and Alternatives (MA)
Grain Products (GP)
Milk Products (MP)

Table D-5 **Food Groups** results for Grade 5, May 19, 1994

Name	Time	Score	Audio	Report
Aaron	5	40	0	VF too low
Adela	11	90	16	Excellent choices. You have a healthy diet.
Barbara	15	40	17	MA too high
Cindy	12	40	18	VF too low, MA too low
David	12	40	0	VF too low, MA too high
Elizabeth	4	40	0	GP too low, VF too low, MP too low
Fay	4	90	16	You could eat a bit more GP and VF
George	10	40	17	MP too low, MA too high
Gina	7	40	17	GP too low, MA too high
Gus	18	40	16	VF too low, MA too low, Sugar, Fat too high
Harry	10	40	17	GP too low, MP too low, MA too high
Tim (deaf)	6	40	0	GP too low
Jeanette	14	40	18	MP too low, MA too high
Karl	21	60	17	MA too high
Lori	15	60	7	MA too high
Marianne	14	90	10	You could eat a bit more GP, VF
Mark	7	40	0	MP too low, MA too high
Ned	10	40	0	VF too low, MP too low, MA too high
Orson	8	40	0	GP too low, VF too low, MP too low, MA too high
Phyllis	12	90	18	Excellent choices. You h[illegible] diet.
Paula	14	100	1	Excellent choices. You have a healthy diet.
Peter	10	40	18	GP too low, MA too high
Rose	7	60	10	MA too high
Russ	12	40	17	MP too low, Meat too low
Sam	15	40	0	GP too low VF too low, MP too low, MA too high
Sandra	22	40	18	VF too low, MA too high
Teresa	16	40	18	GP too low, MA too high
Vera	16	40	17	MA too high
Mean	11.7	51.4	15.2	
SD	4.7	20.3	4.6	
n = 28				

Note: Vegetables and Fruits (VF)
Meat and Alternatives (MA)
Grain Products (GP)
Milk Products (MP)

Table D-6. **Metric City** results for Grade 5, March 7, 1994

Name	Time	Score	Level	Audio H	Visual H	AList	VList
Aaron	17	38	1	10	2	8	0
Adela	19	62	5	1	3	1	2
Barbara	32	50	3	8	8	1	10
Cindy	32	60	4	6	2	1	4
David	15	50	1	2	4	2	3
Elizabeth	27	56	3	1	8	0	4
Fay	12	90	5	0	0	0	3
George	33	38	3	6	28	2	3
Gina	19	60	5	6	0	1	5
Gus	33	53	3	3	10	0	1
Harry	22	58	5	8	2	0	1
Tim (deaf)	30	60	3	0	6	0	2
Jeanette	32	47	5	14	9	0	3
Karl	27	51	2	1	10	3	7
Lori	27	50	3	6	7	2	2
Marianne	12	72	5	0	3	0	2
Mark							
Ned	36	48	3	6	8	2	5
Orson							
Phyllis	15	60	3	2	4	1	2
Paula	6	71	3	0	3	0	2
Peter	11	64	3	0	2	3	4
Rose							
Russ	28	55	5	3	6	3	5
Sam	18	54	3	0	12	0	0
Sandra	16	69	5	3	0	1	0
Teresa							
Vera	11	55	5	2	11	0	3
Mean	22.08	57.13	3.58	3.67	6.17	1.29	3.04
SD	8.95	10.97	1.29	3.69	5.87	1.76	2.24
n = 24							
AV choices				24	24	24	24
AV totals				88	148	31	73

Note. Level is the difficulty level achieved. Each level has 5 questions.
Audio H represents audio hints requested after two errors.
Visual H represents visual hints requested after two errors.
AList represents a request to have the audio explanation of the city's structure.
VList represents a request to see the visual explanation of the city's structure.

Table D-7. **Metric City/Town** results for Grade 5, March 10, 1994

Name	Lesson	Time	Score	Level	Audio H	Visual H	AList	VList
Aaron	Town	9	54	5	7	1	3	1
Adela	Town	4	77	5	0	0	0	0
Barbara	City	22	56	5	7	8	0	4
Cindy	Town	6	81	5	0	0	0	1
David	Town	7	66	2	0	2	0	3
Elizabeth	City	23	60	4	3	4	1	3
Fay	City	4	100	5	0	0	0	1
George	City	14	56	5	1	11	0	1
Gina	Town	4	81	5	0	3	1	2
Gus	Town	5	72	5	0	1	0	0
Harry	Town	7	64	5	2	0	0	0
Tim (deaf)	Town	5	87	5	0	1	0	2
Jeanette	Town	15	60	5	3	3	0	1
Karl	Town	12	65	5	0	5	0	5
Lori	Town	8	85	5	0	0	0	2
Marianne	Town	6	100	5	0	0	0	2
Mark	Town	6	5[illegible]	5	4	1	0	0
Ned	Town	22	48	5	6	3	1	0
Orson	Town	12	57	5	4	0	6	0
Phyllis	Town	10	64	5	0	4	0	1
Paula	City	5	71	5	0	0	0	0
Peter	Town	5	93	5	0	0	1	0
Rose								
Russ	Town	13	52	5	0	4	0	4
Sam	City	7	54	2	0	6	0	0
Sandra	Town	6	100	5	0	0	0	2
Teresa	Town	10	85	5	0	0	0	4
Vera	Town	4	93	5	1	2	0	0
Mean		9.30	71.70	4.74	2.11	3.28	0.65	1.95
SD		5.69	16.56	0.81	2.54	2.87	1.46	1.47
n = 27								
AV choices					18	18	20	20
AV totals					38	59	13	39

Note: Level is the difficulty level achieved. Each level has 5 questions.
Audio H represents audio hints requested after two errors.
Visual H represents visual hints requested after two errors.
AList represents a request to have the audio explanation of the city's structure.
VList represents a request to see the visual explanation of the city's structure.

Table D-8. **Place Value** results for Grade 5. Sept. 30, 1993

	Regular Class				Non-participating Class				
Name	Time	Tries/48	AReq	VReq	Name	Time	Tries/48	AReq	VReq
David	4		6	0	Bob	13	55	3	2
David	4		3	0	Connie	12	59	0	0
Tim (deaf)	5	51	0	0	Curt	12	77	4	0
Karl	11	62	2	0	Darren	1		1	1
Ned	14	59	2	2	Fred	10	55	1	1
Orson	19	66	0	0	Gary	11	64	0	1
Orson	19	58	0	0	Kerry	1		1	0
Orson	5	50	0	0	Mary	1		0	1
Phyllis	6	54	0	0	Nellie	17	68	3	1
Rose	5	54	0	0	Rita	12	58	4	2
Sam	25	72	0	0					
Mean	10.6	58.4	3.3	0.5		9.0	62.3	1.9	1.0
SD	7.5	7.2	1.9	1.0		5.8	8.0	1.6	0.7
n	11					10			
AV choices			4	4				9	9
AV totals			13	2				17	9

Note: Scores were not recorded in this lesson if students quit before the end.

Table D-9. **Punctuation Tutorial** results for Grade 5, February 3, 7, 10, 1994

	February 3			February 7			February 10		
Name	Time	Tutorials	Result	Time	Tutorials	Result	Time	Tutorials	Result
Aaron	30	5	46	20	5	65	15	5	67
Adela	24	6	54	16	5	65	11	3	80
Barbara	33	6	44	27	4	48	21	4	61
Cindy	19	6		15	5	61	11	1	73
David	39	6	52	27	5	63			
Elizabeth				17	3	78	11	3	90
Fay	21	5	67	12	2	89	8	1	94
George	25	4	40	11	4	69	6	2	92
Gina	20	5	59	16	5	71			
Gus	30	6	56	14	1	63	16	4	77
Harry	20	4		14	2	68	17	4	81
Tim (deaf)				11	3	66	5	2	94
Jeanette	39	5	45						
Karl	32	5	52	23	5	63	16	5	73
Lori	28	4	51	26	6	65	17	4	77
Marianne	13	3	62	13	3	69	9	3	88
Mark	18	4	61	33	5	79	13	3	88
Ned	35	6	53	26	6	58	35	6	58
Orson	33	6	51				24	6	71
Phyllis	33	5	57	14	3	87	19	3	79
Paula	19	5	56	35	4	62	12	2	70
Peter	29	6	56	15	4	79	15	5	77
Rose	18	4	83	12	3	91	9	2	93
Russ	26	6	47	21	5	64			
Sam	32	6		30	5	62	23	5	62
Sandra	34	5	56	26	4	74	19	4	72
Teresa	24	4		19	4	85	16	2	78
Vera				17	5	65	12	4	84
Mean	27.0	5.1	54.7	19.6	4.1	69.6	15.0	3.5	78.1
SD	7.1	0.9	9.8	7.1	1.3	10.4	6.6	1.4	10.6
n	25			26			24		

Table D-10. **Respiratory System** results for Grade 5, April 5, 1994

			Definitions Section		Animation Sections	
Name	Time	Score	Audio	Visual	Audio	Visual
Aaron	17	27	1	0	1	0
Adela	13	47	2	0	1	0
Barbara	18	47	6	2	0	1
Cindy	12	71	5	0	1	0
David	17	29	4	3	1	0
Elizabeth	19	83	6	7	0	1
Fay	15	86	5	1	0	1
George	15	76	5	4	1	0
Gina	11	66	1	5	0	1
Gus	17	60	8	0	1	0
Harry	14	90	1	11	1	0
Tim (deaf)	15	83	0	5	0	1
Jeanette	24	58	5	5	0	2
Karl	24	43	4	1	0	1
Lori	14	66	5	0	1	0
Marianne						
Mark	8		5	0	1	0
Ned	17	47	10	2	1	0
Orson	18	37	5	0	1	0
Phyllis	17	86	2	10	1	0
Paula	16	62	2	5	0	1
Peter	13	66	5	0	1	0
Rose	9	76	0	5	0	1
Russ	14	58	2	1	1	0
Sam	8		5	1	1	0
Sandra						
Teresa	17	76	6	1	1	0
Vera	15	86	5	0	1	1
Mean	15.27	63.58	3.96	2.65	0.65	0.42
SD	3.95	18.72	2.44	3.16	0.49	0.58
n = 26						
AV choices			26	26	26	26
AV totals			103	69	17	11

Table D-11. **Respiratory System** results for Grade 5, April 7, 1994

Name	Time	Score	Definitions Audio	Definitions Visual	Animations Audio	Animations Visual
Aaron	5	71	1	1		
Adela	6	66			0	1
Barbara	4	55				
Cindy	10	76			0	1
David	14	71	5	0	1	0
Elizabeth	10	90	0	5		
Fay	6	90	3	4	0	1
George	12	86	0	5	0	2
Gina	8	80	0	5	1	0
Gus	7	83	2	4		
Harry	4	90				
Tim (deaf)	8	76	0	15	0	2
Jeanette						
Karl	10	90	3	2	1	0
Lori	11	76	5	0	1	0
Marianne	14	66	10	3	2	0
Mark	4	83				
Ned	19	74	5	0	0	1
Orson	5	100	8	0		
Phyllis	8	90	0	4	0	1
Paula	2	83				
Peter	10	100	1	0	1	0
Rose	5	100	2	3	0	1
Russ	8	58	1	1		
Sam	16	66	10	0	2	0
Sandra	12	76	1	2	1	0
Teresa	12	90	3	3	1	0
Vera	5	83	5	0	1	0
Mean	8.70	80.33	3.10	2.71	0.67	0.56
SD	4.14	12.13	3.18	3.39	0.69	0.70
n = 27						
AV choices			21	21	18	18
AV totals			65	57	12	10

Table D-12. **Respiratory System** results for Grade 5, April 14, 1994

			Definitions Section		Animation Sections	
Name	Time	Score	Audio	Visual	Audio	Visual
Aaron	6	100	1	1		
Adela	5	83				
Barbara	8	100	4	0		
Cindy	11	90	7	1	1	0
David						
Elizabeth	9	66	7	0	1	0
Fay	5	100	2	3		
George	9	100	5	1	1	0
Gina	3	100	2	3		
Gus	2	90	1	0		
Harry	4	100	3	1		
Tim (deaf)	8	100	1	5	0	1
Jeanette						
Karl	5	100	5	0		
Lori	9	100	5	1	1	0
Marianne	11	100	5	0	1	0
Mark	3	90				
Ned	10	90	5	0	1	0
Orson	9	90				
Phyllis	11	100	7	0		
Paula	1	100	1	0		
Peter	8	100	5	0	1	0
Rose	1	90			1	0
Russ	11	83	5	4	1	0
Sam	10	62	6	0		
Sandra						
Teresa	8	100	0	4	1	0
Vera	4	100	5	0		
Mean	6.84	93.36	3.90	1.14	0.91	0.09
SD	3.30	10.56	2.23	1.62	0.30	0.30
n = 25						
AV choices			21	21	11	11
AV totals			82	24	10	1

Table D-13. **Respiratory System** results for students in another Grade 5 class, April 8, 1994

			Definitions Section		Animation Sections	
Name	Time	Score	Audio	Visual	Audio	Visual
Barry	15	71	6	0	1	0
Doris	19	76			1	0
Fred	15	41	5	1	0	1
Gerry	15	68	6	0	1	0
Jed	6	66				
Kit	19	52	5	2	1	0
Lori-ann	9	66	5	0	1	0
Morris	14	90	7	2	1	0
Pete	12	90	6	3	1	0
Raul	14	76	6	1	1	0
Tessie	16	80	6	0	1	0
Tom	13	74	2	1	1	0
Mean	13.92	70.83	5.40	1.00	0.91	0.09
SD	3.70	14.08	1.35	1.05	0.30	0.30
n = 12						
AV choices			10	10	11	11
AV totals			54	10	10	1

Table D-14. **Rounding Off** results for Grade 5, October 7, 12, 1993

Name	October 7 Time	October 7 Tries/20	October 7 AReq	October 7 VReq	October 12 Time	October 12 Tries/20	October 12 AReq	October 12 VReq
Aaron	16		8	8	24	100	10	13
Adela					10	23		
Barbara	23	56	2	9	10	30	0	3
Cindy	11	26	2	1	11	21		
David	4		3	1	11	23	1	0
Elizabeth					6	26		
Fay	6	21	1	0	4	21		
George	8	23	1	1	7	21	1	1
Gina	3		1	2	6	26	0	1
Gus					10	23	1	0
Harry	13	25	1	1	7	22		
Tim (deaf)	7	26	0	2	8	38	0	3
Jeanette	19	37	1	6	10	28	2	4
Karl	17	42	2	1	10	34		
Lori	13	32	1	2	6	24		
Marianne	10		5	0	6	21		
Mark	9	25	2	2	4	21		
Ned	6		2	3	11	23	6	0
Orson	29	29	16	3	3		1	0
Phyllis	2		1	0	8	21		
Paula					12	22		
Peter	16	35	3	1	7	24		
Randy	10	22	1	0	4	23		
Rose	6	21						
Russ	1		1	0	8	21		
Sam	17	56						
Sandra					9	25		
Teresa	10		1	0	12	30		
Vera	11	34	2	5	3	24		
Mean	11.13	31.88	2.59	2.18	8.41	27.50	2.20	2.50
SD	6.80	11.23	3.45	2.59	4.15	15.40	3.26	3.98
n	24				27			
AV choices			22	22			10	10
AV totals			57	48			22	25

Note: Scores were not recorded in this lesson if students quit before the end.

Table D-15. **Sentence Tutorial** results for Grade 5, Feb. 15, 1994

	First Day Use					Repetition				
Name	Time	Score	Tutorials	Audio	Visual	Time	Score	Tutorials	Audio	Visual
Aaron	11	54	4	9	9					
Adela	5	69	2							
Barbara	13	57	4	3	3					
Cindy	8	70	1	2	2					
David	11	57	3	2	2					
Elizabeth	10	70	3	2	2	7	76	2		
Fay	10	85	2	1	1	4	92	2		
George	5	80	2							
Gina										
Gus	10	71	3							
Harry	9	74	2	2	2					
Tim (deaf)	6	64	3	0	1					
Jeanette										
Karl	10	66	3	3	3					
Lori	9	83	2							
Marianne	5	87	1	1	1					
Mark	9	65	3	1	1					
Ned	10	50	3	1	1					
Orson	10	56	[illegible]							
Phyllis	12	64			3	9	84	1		
Paula	9	60								
Peter	8	[illegible]				7	67	2		
Rose	10				1					
Russ	10				[illegible]					
Sam	11									
Sandra	7				[illegible]					
Teresa	8									
Vera	8	6[illegible]		2	3					
Mean	9.00	68.88	2.69	2.22	2.39	6.75	79.75	1.75		
SD	2.10	11.59	0.88	1.91	1.91	3.51	36.85	0.89		
n	26					4				
AV choices				18	18					
AV totals				40	43					

Table D-16. **Sentence Tutorial** results for Grade 5, Feb. 17, 1994

	Second Day Use					Repetition				
Name	Time	Score	Tutorials	Audio	Visual	Time	Score	Tutorials	Audio	Visual
Aaron	7	51	4	2	2					
Adela	6	67	2							
Barbara	10	56	2	2	2					
Cindy	8	83	2							
David	10	71	2							
Elizabeth	6	88	1			6	83	2		
Fay	5	91	1			2	100	0		
George	7	76	4							
Gina	7	65	2			5	80	2		
Gus	11	72	3							
Harry	4	89	1			2	100	0		
Tim (deaf)	5	90	3	0	1					
Jeanette	8	60	4							
Karl	8	60	2							
Lori	5	87	2							
Marianne	5	90	2							
Mark										
Ned	10	54	3							
Orson	6	66	4							
Phyllis	6	90	2							
Paula	7	60	3							
Peter	7	68	3			5	87	3		
Rose	4	100	0							
Russ	5	69	4	1	1					
Sam	11	43	3	0	1					
Sandra	7	88	2			8	84	3		
Teresa	21	63	4							
Vera	5	88	2							
Mean	7.44	73.52	2.48	1.00	1.40	4.67	89.00	1.67		
SD	3.39	15.17	1.09	1.00	0.55	2.34	8.81	1.37		
n	27					6				
AV choices				5	5					
AV totals				5	7					

Table D-17. **Spelling 2** results for Grade 5, April 25, 1994

	First Day Use							Repetition						
Name	Time	Score	Dir	Sent	Fdbk	Ans	Word	Time	Score	Dir	Sent	Fdbk	Ans	Word
Aaron	9	56	9	9	9	9	22	4	82	4	4	4	4	1
Adela	5	93	5	5	5	5	0	3	100	3	3	3	3	0
Barbara	10	70	10	10	10	10	3	4	87	4	4	4	4	1
Cindy	5	93	3	5	3	4	1	5	100	1	5	4	3	2
David	6	82	6	6	6	6	1	4	82	4	4	4	4	0
Elizabeth	6	93	3	3	3	3	12	4	100	0	4	0	0	1
Fay	3	93	3	3	3	3	0	2	100	2	2	2	2	0
George	4	87	1	4	4	4	2	3	87	0	2	3	3	3
Gina	3	100	3	3	3	3	0	3	93	3	3	3	3	0
Gus	5	100	3	3	3	3	13	4	93	0	0	0	0	4
Harry	6	100	6	6	6	6	10	4	100	4	4	4	4	0
Tim(deaf)	7	100	0	0	0	0	15							
Jeanette	6	58	6	6	6	6	2	4	93	4	4	4	4	1
Karl	5	100	5	5	5	5	0	4	100	4	4	4	4	0
Lori	5	100	5	5	5	5	4	3	100	3	3	3	3	0
Marianne	3	93	3	3	3	3	1							
Mark	4	100	4	4	4	4	0	3	100	3	3	3	3	0
Ned	6	73	6	6	6	6	1	4	100	4	4	4	4	0
Orson	6	77	6	6	6	6	1							
Phyllis	6	87	6	6	6	6	1	3	100	3	3	3	3	0
Paula	7	73	0	7	7	0	10	2	100	0	2	2	2	0
Peter	3	100	3	3	3	3	0	3	100	3	3	3	3	0
Rose	5	100	5	5	5	5	2	3	100	3	3	3	3	0
Russ	8	70	8	8	8	8	3	3	100	3	3	3	3	1
Sam	8	66	4	8	8	8	21	3	66	0	3	3	3	7
Sandra	4	100	4	4	4	4	0	3	93	3	3	3	3	0
Teresa														
Vera	7	66	7	0	7	7	13	5	100	5	0	5	5	3
Mean	5.6	86.3	4.6	4.9	5.1	4.9	5.1	3.5	94.8	2.6	3.0	3.1	3.0	1.0
SD	1.8	14.7	2.4	2.4	2.2	2.4	6.7	0.8	8.6	1.6	1.2	1.2	1.2	1.7
n	27							24						
AV choices			27	27	27	27	27			24	24	24	24	24
AV totals			124	133	138	132	138			63	73	74	73	24

Note: Dir = spoken directions
Sent = spoken sentence
Fdbk = spoken feedback
Ans = spelled word after two mistakes
Word = spoken repetition of required word

Table D-18. **Spelling 2, 3** results for Grade 5, April 28, 1994

	Spelling 2							Spelling 3						
Name	Time	Score	Dir	Sent	Fdbk	Ans	Word	Time	Score	Dir	Sent	Fdbk	Ans	Word
Aaron	3	93	3	3	3	3	1	3	76	3	3	3	3	1
Adela	3	100	3	3	3	3	0	2	100	2	2	2	2	0
Barbara	8	100	8	8	8	8	10	3	83	3	3	3	3	2
Cindy	4	87	0	2	0	0	1	3	100	0	2	0	0	6
David	3	93	3	3	3	3	0	2	100	2	2	2	2	0
Elizabeth	3	82	0	3	0	0	0	2	83	0	2	0	0	0
Fay	3	100	3	3	3	3	0	2	100	2	2	2	2	0
George	3	93	0	3	3	3	2	2	90	0	2	2	2	0
Gina	3	100	3	3	3	3	0	2	100	2	2	2	2	0
Gus	4	100	3	3	3	2	13	2	100	0	0	0	0	7
Harry														
Tim	3	100	0	0	0	0	11	2	100	0	0	0	0	12
Jeanette	4	87	4	4	4	4	1	2	100	2	2	2	2	0
Karl	5	100	5	5	5	5	0	2	90	2	2	2	2	0
Lori								3	90	3	3	3	3	1
Marianne	2	100	2	2	2	2	0	2	100	2	2	2	2	0
Mark	4	100	3	4	4	4	0	2	100	2	2	1	2	0
Ned	6	100	6	6	6	6	0	6	76	6	6	6	6	3
Orson	5	100	5	5	5	5	0							
Phyllis	3	100	3	3	3	3	0	2	100	2	2	2	2	0
Paula	3	100	0	3	3	3	0	3	83	0	3	3	0	0
Peter	3	100	3	3	3	3	0	2	100	2	2	2	2	0
Rose	4	93	4	4	4	4	0	2	100	2	2	2	2	0
Russ	4	100	4	4	4	4	0	3	100	3	3	3	3	1
Sam	4	73	0	4	4	4	16							
Sandra	4	100	4	4	4	4	1	3	100	3	3	3	3	0
Teresa	4	87	1	4	4	4	0	3	90	0	3	3	3	1
Vera	4	100	4	3	4	4	1	2	100	2	0	2	2	10
Mean	3.8	95.7	2.8	3.5	3.4	3.3	2.2	2.5	94.4	1.8	2.2	2.1	2.0	1.8
SD	1.2	7.1	2.1	1.4	1.7	1.7	4.6	0.9	8.3	1.4	1.2	1.3	1.3	3.3
n	26							25						
AV choices			26	26	26	26	26			25	25	25	25	25
AV totals			74	92	88	87	57			45	55	52	50	44

Note: Dir = spoken directions
Sent = spoken sentence
Fdbk = spoken feedback
Ans = spelled answer after two errors
Word = repetition of required word

Table D-19. **Spelling #4/#5** results for Grade 5, June 6, 1994

Nam	Spelling #4							Spelling #5						
	Time	Score	Dir	Sent	Fdbk	Ans	Word	Time	Score	Dir	Sent	Fdbk	Ans	Word
Aaron														
Adela	5	85	12	0	12	0	15	7	52	7	0	4	0	14
Barbara	5	75	12	5	7	0	10	7	58	10	10	0	0	5
Cindy	5	100	0	12	0	0	12	4	76	0	10	0	0	1
David	7	92	12	11	1	11	2	11	76	12	0	2	0	11
Elizabeth	3	100	0	10	1	9	5	4	90	2	9	10	0	3
Fay	3	100	12	0	12	0	12	3	100	12	0	12	0	11
George	3	100	0	9	12	1	4	4	66	0	10	0	10	2
Gina	3	100	3	12	12	12	1	4	100	10	8	10	4	3
Cus	4	100	0	0	0	0	12	4	100	0	0	0	0	13
Harry	3	92	12	1	12	0	30	3	76	10	10	10	0	4
Tim	3	100	0	0	0	0	15	2	100	0	0	0	0	5
Jeanette	6	85	12	11	12	0	3	10	45	4	10	4	8	4
Karl	5	100	11	8	12	0	7	4	71	10	10	10	0	1
Lori	8	85	12	0	12	0	15	9	40	10	0	10	0	20
Marianne	3	100	5	12	12	12	2	4	90	9	9	10	9	4
Mark	4	100	12	12	12	12	2	7	83	10	10	10	10	5
Ned	6	70	12	12	12	12	3	8	43	10	10	10	10	1
Orson	5	100	12	0	12	0	15	6	100	10	0	10	0	13
Phyllis														
Paula	4	100	1	11	12	11	3	4	62	1	10	6	8	2
Peter	3	85	12	6	12	7	7	2	71	10	10	10	10	2
Rose	4	92	11	0	6	10	12	3	100	10	0	10	0	12
Russ	6	46	12	10	12	4	5	6	58	10	10	10	0	2
Sam	4	100	12	11	12	0	13	11	62	10	10	10	0	18
Sandra	4	80	12	11	11	0	1	5	83	10	10	10	0	1
Teresa	4	100	1	12	12	12	7	7	66	0	10	10	0	14
Vera	2	85	3	0	12	0	14	8	43	0	0	10	2	20
Mean	4.3	91.2	7.8	6.8	9.3	4.3	8.7	5.7	73.5	6.8	6.4	7.2	2.7	7.3
SD	1.4	12.9	5.4	5.2	4.7	5.4	6.7	2.7	20.1	4.6	4.8	4.3	4.2	6.3
n	26							26						
AV choices			26	26	26	26	26			26	26	26	26	26
AV total			203	176	242	113	227			177	166	188	71	191

Note: Dir = spoken directions
Sent = spoken sentence
Fdbk = spoken feedback
Ans = spelled answer after two errors
Word = repetition of required word

Table D-20. **Arithmetic.2** results for Grade 2, April 5, /7, 1994

Name	April 5 Time	April 5 Score	April 7 Time	April 7 Score
Arlene	21	80	8	85
Anne	14	77		
Cameron	18	88	13	88
Corry			10	66
Dawn			10	85
Ernest	9	92	5	88
Francis	8	100	4	96
Jessie	14	82	14	88
Inez	10	80	6	88
Gina	14	82	12	85
Lorne	7	72	6	72
Carrie	8	75	8	92
Morna	22	68	13	82
Nellie	42	61	8	68
Larry	9	82	7	72
Patricia	15	70	5	96
Peter	18	77	9	82
Rose	20	70	11	85
Samuel	9	70	5	96
Tom	16	77	12	85
Wayne	18	85	7	96
Mean	13.7	79.7	8.2	74.7
SD	8.6	9.7	3.6	27.9
n	22		23	

Table D-21. **Blends 1, 2** results for Grade 2, October 12, 1993

Name	Blends 1 Time	Blends 1 Audio request	Blends 1 Spoken directions	Blends 1 Written directions	Blends 2 Time	Blends 2 Audio request	Blends 2 Spoken directions	Blends 2 Written directions
Arlene	11	24	2	0				
Anne	11	17	3	5	8	11	2	0
Cameron	8	16	2	0	5	16		
Corry	6	7			7	19		
Dawn	9	13			6	13		
Ernest	6	6			3	0		
Francis	6	4	4	3	5	7		
Jessie								
Inez	9	8	1	2	6	7	1	0
Gina	9	1	2	0	5	6		
Lorne	5	0			3	3	1	1
Carrie					4	1		
Morna	8	26			7	17		
Nellie	9	1	1	1	5	5		
Larry	12	6	1	0				
Patricia	5	6	0	2	7	16		
Peter	7	7	1	2	4	4		
Rose	9	17	2	1	6	3	1	1
Samuel								
Toni	4	7			4	6		
Wayne	4	5	0	1	3	2		
Mean	7.0	20.8	2.3	2.7	5.2	8.0	1.3	0.5
SD	2.7	29.3	2.9	3.8	1.6	6.1	0.5	0.6
n	21				17			
AV choices		21	15	15		17	4	4
AV totals		171	19	17		136	5	2

Table D-22. **Blends 1** results for Grade 2, March 10, 1994

Name	Time	Audio request	Spoken directions	Written directions
Arlene	6	8		
Anne	6	28		
Cameron	8	14		
Corry	7	21		
Dawn	4	1		
Ernest	3	0		
Francis	3	1		
Jessie	6	15	3	0
Inez	6	5		
Gina	9	12		
Lorne	3	1		
Carrie	4	0	0	2
Morna	7	9		
Nellie	4	9		
Patricia	5	1		
Peter	6	5	1	0
Rose	3	2		
Tom	5	1	0	2
Wayne	5	12	4	0
Mean	5.3	7.6	1.6	0.8
SD	1.8	7.9	1.8	1.1
n = 19				
AV choices		19	5	5
AV totals		145	8	4

Table D-23. **Blends 1, 2** results for Grade 2, April 14, 18, 1994

Name	Blends 1 Time	Score	Audio request	Spoken dir.	Written dir.	Blends 2 Time	Score	Audio request	Spoken dir.	Written dir.
Arlene	4	90	4			5	90	2		
Anne	6	90	9			7	65	15		
Cameron	5	100	16	1	0	3	95	10		
Corry	6	80	8	0	2	5	90	6	0	1
Dawn	4	85	2			4	95	1		
Ernest	3	90	0			3	100	0		
Francis	3	95	0			4	85	3		
Jessie	3	100	11	2	0	2	95	11	3	0
Inez	4	70	0			4	75	5		
Gina	6	75	6			5	90	8		
Lorne	6	100	0	1	0	3	100	2		
Carrie	3	100	0	0	2	3	85	0		
Moma	7	90	12	1	0	3	100	3		
Nellie	5	65	3			6	50	1		
Larry	4	70	8			4	90	4		
Patricia	4	100	9			4	90	8	1	1
Peter	5	100	1			4	90	2		
Rose	6	95	7	1	0	5	90	5		
Samuel	7	80	25	3	2	3	100	13		
Tom	4		2	1	0	4		5		
Wayne	4	90	8	2	0	3	100	1		
Mean	4.7	88.3	6.2	1.2	0.6	4.0	88.8	5.0	1.3	0.7
SD	1.3	11.4	6.3	0.9	1.0	1.2	12.7	4.3	1.5	0.6
n	21					21				
AV choices			21	10	10			21	3	3
AV totals			131	12	6			105	4	2

Table D-24. **Blends 3** results for Grade 2, April 18, 1994

Name	Time	Score	Audio request	Spoken directions	Written directions
Arlene	6	85	6		
Anne	4	100	8		
Cameron	3	100	9		
Corry	6	85	2		
Dawn	4	95	4		
Ernest	4	85	3	1	0
Francis	4	100	3		
Jessie	3	95	4		
Inez	3	95	3		
Gina	5	80	4		
Lorne	3	100	7		
Carrie	3	90		0	1
Morna	4	100	11		
Nellie	5	65	13		
Larry	4	90	2		
Patricia	4	100	8	1	0
Peter	4	90	1		
Rose	4	100	4		
Samuel	3	95	12		
Tom	3		1		
Wayne	5	95	6	1	0
Mean	4.0	92.3	5.3	0.8	0.3
SD	0.9	9.0	3.7	0.5	0.5
n = 21					
AV choices			20	4	4
AV totals			111	3	1

Table D-25. **Canada Quiz** results for Grade 2. Jan. 31, 1994

Name	Score	Spoken directions	Audio support of a word
Arlene	7		0
Anne	8	14	3
Cameron	7	9	0
Corry	9	5	0
Dawn			
Ernest	10		0
Francis	8	6	0
Jessie	10		0
Inez			
Gina	10		0
Morna	9	13	0
Nellie	7	12	3
Larry	7	7	0
Patricia	8	15	1
Peter	10		0
Rose	8	2	0
Samuel	6	12	0
Tom	9		0
Wayne	8	5	0
Mean	8.3	9.1	2.3
SD	1.3	4.3	1.2
n = 17			
AV choices		11	3
AV totals		100	7

Table D-26. **Changing Money** results for Grade 2, Feb. 7, 10, 1994

	February 7			February 10		
Name	Time	Score	Audio request	Time	Score	Audio request
Arlene				20	79	
Anne				23	75	11
Cameron	20	87	1	20	82	
Corry	14	75		13	81	
Dawn	8	80	2	6	95	2
Ernest	11	83	2	11	64	1
Francis	10	72	3			
Jessie	11	89	6			
Inez	10	68	9	11	64	1
Gina	15	86	1	9	94	
Lorne				17	77	
Carrie	8	77	8	10	79	
Morna	15	83		16	88	
Nellie	14	53		17	55	6
Larry	16	51	6	17	53	5
Patricia	18	66	5			
Peter	19	85		8	75	5
Rose	16	87	2	13	80	
Samuel	10	61	4			
Tom	11	65	1			
Wayne	10	53	7	7	85	4
Mean	13.1	73.4	4.1	13.6	76.6	4.4
SD	3.7	12.8	2.8	5.1	12.3	3.3
n	18			16		
AV choices			14			8
AV totals			57			35

Table D-27. **Ponds** results for Grade 2, May 6, 1994

	Trial 1						Trial 2					
	Default Audio On			Default Audio Off			Default Audio On			Default Audio Off		
Name	Time	Score	Audio req.	Time	Score	Audio req.	Time	Score	Audio req.	Time	Score	Audio req.
Arlene				6	66	11	4	71	12			
Anne	7	71	11							4	52	0
Cameron				9	71	11	6	62	12			
Corry	3	55	12							6	100	8
Dawn	3	71	12							6	71	11
Ernest				3	71	11	3	52	12			
Francis	4	100	10							7	83	11
Jessie				6	90	10	4	100	12			
Inez	7	71	10							4	100	0
Gina	4	83	12							8	76	11
Lorne				4	76	11	3	100	12			
Carrie	4	100	7							3	90	0
Morna	7	58	12							3	83	11
Nellie	8	45	12							5	47	8
Larry	6	100	1							7	62	5
Patricia				6	100	10						
Peter	5	100	12							2	83	0
Rose	5	90	12							4	100	0
Samuel	6	76	12							6	100	0
Tom	3	71	12							2	90	0
Wayne				3	83	11	4	90	12			
Mean	5.1	77.9	10.5	5.3	79.6	10.7	4.0	79.2	12.0	4.8	81.2	4.6
SD	1.7	18.2	3.1	2.1	12.1	0.5	1.1	20.4	0.0	1.9	17.8	5.1
n	14			7			6			14		
AV choices			14			7			6			14
AV totals			147			75			72			65

Table D-28. **Rhymes/Rhymes2** results for Grade 2, Sept. 16, 21, 1994

Name	September 16				September 21			
	Time	Tries	Audio Req. in Sample	Audio Req. in Questions	Time	Tries	Audio Req. in Sample	Audio Req. in Questions
Arlene	7	6	0	8	6	2	4	11
Anne	16	12	9	132	13	19	10	50
Cameron	16	19	10	81	12	14	3	77
Corry								
Dawn	7	16	1	16	8	3	3	74
Ernest	7	9	20	1				
Francis	8	13	8	7	5	6	0	3
Jessie	14	11	0	8	6	9	4	5
Inez	6	23	8	15				
Gina	17	13	5	74	8	30	5	28
Lorne	5	7	0	4	3	4	2	5
Carrie	8	2	0	11	4	1		1
Morna	17	16	3	78	15	16	9	82
Nellie	21	8	6	56	8	12	3	52
Larry	9	16	5	10	9	7	2	56
Patricia	17	4	10	71	8	10	0	71
Peter	4	6	0	6	6	9	3	11
Rose	10	8	0	21	6	4	1	14
Samuel	16	17	14	34				
Tom	3	4	0	1	5	3	0	13
Wayne	6	9	10	11				
Mean	10.7	11.0	5.5	32.3	7.6	9.3	3.3	34.6
SD	5.4	5.6	5.7	36.7	3.3	7.6	3.0	30.4
n	20				16			
AV choices			20	20			15	16
AV totals			109	645			49	553

Table D-29. **Spelling 2** results for Grade 2, April 25, 28, 1994

	April 25							April 28						
Name	Time	Score	Dir	Sent	Fdbk	Ans	Wd.	Time	Score	Dir	Sent	Fdbk	Ans	Wd
Arlene	12	93	14	14	14	14	16	11	93	14	14	14	14	11
Anne	37	60	6	6	6	5	34	31	38	14	14	14	14	8
Cameron	11	93	14	14	14	14	10	7	93	14	14	14	14	4
Corry	13	66	14	14	14	14	17	12	48	14	14	14	14	25
Dawn	13	82	14	14	14	14	9	6	77	14	14	14	14	0
Ernest	5	93	14	14	14	14	2	6	58	14	14	14	14	0
Francis	9	82	4	6	6	7	8	6	100	8	8	8	8	11
Jessie	14	82	0	0	0	0	19	10	87	0	0	0	0	10
Inez	6	93	0	14	14	14	7	5	82	14	14	14	14	1
Gina	22	66	14	12	13	13	11	10	73	14	14	14	14	5
Lorne	6	100	5	13	14	14	7	2	93	2	12	13	13	3
Carrie	6	100	6	14	14	14	3	4	93	0	14	14	14	0
Morna								14	51	14	14	14	14	2
Nellie	28	58	14	14	14	14	20	15	41	14	14	14	14	18
Larry	7	82	14	14	14	14	7	6	77	0	13	0	0	3
Patricia	11	100	14	14	14	14	10	9	100	14	14	14	14	2
Peter	9	87	14	14	14	14	3	7	100	14	14	14	14	0
Rose	12	82	14	14	14	14	2	6	100	14	14	14	14	
Samuel	13	92	14	14	14	14	8							
Tom	5	82	14	14	14	14	9	2	100	14	14	14	14	0
Wayne	7	87	10	10	10	10	10	7	100	7	7	7	7	
Mean	12.3	84.0	10.7	12.2	12.3	12.3	10.6	8.8	80.2	10.7	12.5	11.9	11.9	5.
SD	8.2	12.8	5.1	3.8	3.8	3.9	7.6	6.3	21.6	5.6	3.6	4.5	4.5	6.
n	20							20						

Note: Dir = spoken directions
Sent = spoken sentence
Fdbk = spoken feedback
Ans = spelled word after two mistakes
Wd. = spoken repetition of required word

Table D-30. **Spelling 3** results for Grade 2, April 28, May 10, 1994

	April 28							May 10						
Name	Time	Score	Dir	Sent	Fdbk	Ans	Wd.	Time	Score	Dir	Sent	Fdbk	Ans	W[illegible]
Arlene	11	83	10	10	10	10	10	8	90	9	10	10	10	[illegible]
Anne	18	62	10	10	10	10	62							
Cameron	14	35	10	10	10	10	2							
Corry	9	45	10	10	10	10	45							
Dawn	5	71	10	10	10	10	0	5	58	10	10	9	10	
Ernest	3	76	10	10	10	10	0	3	100	5	10	0	10	
Francis	4	100	10	10	10	10	1	4	90	0	0	0	0	
Jessie	8	52	0	0	0	0	10	12	50	2	8	6	8	2
Inez	3	90	10	10	10	10	0	2	100	10	10	10	10	
Gina	14	52	10	10	10	10	2	7	71	10	10	10	10	
Lorne								1	90	0	10	5	6	
Carrie	4	71	0	10	10	10	0	4	76	0	10	1	10	
Morna	15	37	10	10	10	10	7							
Nellie	14	24	10	[illegible]	10	10	8							
Larry	5	83	10	10	10	10	1	4	76	10	10	10	10	
Patricia	4	83	10	10	10	10	1	6	83	10	10	10	10	
Peter	5	100	10	10	10	10	1	5	71	10	10	10	10	
Rose	12	66	10	10	10	10	10							
Samuel								21	62	2	2	2	2	[illegible]
Tom	1	100	10	10	10	10	0							
Wayne	8	66	9	9	9	9	2	4	90	6	0	4	0	
Mean	8.3	68.2	8.9	9.4	9.4	9.4	8.5	6.1	79.1	6.0	7.9	6.2	7.6	3
SD	5.0	22.8	3.1	2.3	2.3	2.3	16.5	5.1	15.4	4.4	4.0	4.1	3.9	6
n	19							14						

Table D-31. **Spelling 4, 5** results for Grade 2, May 10, 1994

	Spelling 4							Spelling 5						
Name	Time	Score	Dir	Sent	Fdbk	Ans	Wd.	Time	Score	Dir	Sent	Fdbk	Ans	Wd
Arlene	14	60	0	10	1	0	1	19	40	1	9	1	0	12
Anne	18	41	12	12	12	0	6							
Cameron	15	50	0	12	12	12	5							
Corry	31	33	6	2	5	2	20							
Dawn	9	42	10	10	0	10	4							
Ernest	5	75	0	9	0	12	4	4	76	1	9	0	10	3
Francis	6	75	2	3	3	1	7	8	55	10	10	10	10	3
Jessie	7	66	0	12	12	12	3	18	47	0	9	5	9	3
Inez	7	75	12	0	12	0	17	6	45	10	0	10	0	9
Gina	18	27	12	12	12	12	2							
Lorne	1	100	0	12	12	0	2	4	50	2	7	10	0	9
Carrie	5	70	0	10	0	10	1	5	62	0	10	0	10	[illegible]
Morna	29	29	12	11	12	11	9							
Nellie	20	26	0	7	0	0	11							
Larry	5	92	12	9	12	0	6	9	50	10	9	10	9	8
Patricia	5	80	12	12	12	12	2	11	47	10	10	10	10	[illegible]
Peter	8	70	12	12	12	12	2	8	76	10	10	10	0	[illegible]
Rose	11	85	0	4	0	4	15	14	43	2	0	10	0	1
Samuel	14	46	12	10	12	10	11							
Tom	2	100	12	10	12	12	3	2	100	10	10	10	0	
Wayne	7	70	2	10	10	10	6	14	33	0	10	8	8	
Mean	11.3	62.5	6.1	9.0	7.8	6.8	6.5	9.4	55.7	5.1	7.9	7.2	5.1	6.
SD	8.2	23.5	5.7	3.7	5.5	5.4	5.4	5.5	18.4	4.8	3.6	4.2	4.9	5.
n	21							13						

APPENDIX E GLOSSARY

BASIC	an acronym for a computer language for beginners (Beginners All-purpose Symbolic Instruction Code).
CAI	an acronym for computer-aided instruction. The computer is used to deliver one part of the instruction.
CBI	an acronym for computer-based instruction. The computer is used to deliver all of the instruction.
CBL	an acronym for computer-based learning. The computer is used as a tool for learning by the student.
CD-ROM	an acronym for Compact Disc Read Only Memory. This is a compact disc which records digital data in textual, graphic, audio or video format.
CMI	an acronym for computer-managed instruction. These programs keep track of student achievement and/or are tools for teacher record keepi
FORTRAN	a computer language used for mathematical and scientific work. Its name was created from formula translating.
Hypermedia	a term to represent a collection of various computer-controlled media which can be accessed in a non-linear fashion.
Hypertext	a term to represent textual material that can be accessed in a non-linea fashion through links placed within the material. For example, clicki on a reference to a poem in Robert Frost's biography would open a window containing that poem on the computer screen. Clicking on a obscure word in that poem would open another window with its definition.

Information-processing approach

a psychological framework in which researchers study the flow of information through the cognitive system. The flow begins with input (stimulus) and ends with output (overt or covert behavior). Between the input and the output are mental processes which can be compared to a computer's processing. These processes act on the input, perform operations on it and store the results. The classical theorists considered human information processing to have four elements: the sensory organs, short-term or working memory, long-term memory, and the muscle systems energized by nerve impulses to perform motor acts. Tennyson (1992) added both executive control and an affective component.

Interface a term referring to that part of the computer program that directly interacts with the person.

Peripherals a term referring to equipment which can be attached to and controlled by a computer. Some examples are printers, CD-ROM drives, videodisc players, modems, scanners.

Stacks a term referring to a collection of "cards" in HyperCard. A stack may represent a computer-assisted lesson, an adventure story, a database, or a videodisc player controller.