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ABSTRACT

This paper focuses on the applications which best suit the microcomputer in an educational setting with emphasis on adapting effective pedagogical practice to the computer's programability and delivery capabilities. Discovery learning and "being told" are identified as two types of computer assisted instruction (CAI) and sample uses of each method are compared and contrasted to identify their strengths and weaknesses. Comparison of these two CAI methods is based on analyses of five components: (1) student reinforcement; (2) full use of the potential of microcomputers; (3) student-computer interactions; (4) knowledge of possible answers and probable mistakes; and (5) existence of an interactive environment. It is pointed out that learning to program in "discovery languages" (LOGO, PILOT) is a powerful skill that all students should have available to them. Implications of CAI for use with special education students are discussed, and specific benefits are suggested for behaviorally disoriented, mentally and physically handicapped, and learning disabled students. Four major components of CAI that assist these students are identified: program patience, program repetition, eagerness of students to use computers, and suitability for discovery learning. Teachers are encouraged to familiarize themselves with programs that teach effectively and to help create programs that ensure superior instruction. A three-page list of references completes the document. (JB)

# Micro-CAI in Education: Some Considerations

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## Micro-CAI in Education: Some Considerations

As microcomputers are increasingly introduced into educational settings two very different sentiments are being expressed by educators. One g. considers the computer to be a technological marvel that will better prepare school children for making the transition into today's computerized society. A significant number of teachers, on the other hand, characterizes the in-classroom microcomputer as a passing fad (Sneibecker, 1981), comparing it to the tachistocopes, overhead projectors and speed readers that once graced their classrooms and now occupy their closets. Yet, increasingly the microcomputer is becoming a component in the educational process implemented in elementary and high school classrooms (Wieck, 1980). Application of computer technology in the classroom, through microcomputing, stems from recent advances made in silicon chips. These electronic miniatures make available the power to run educational programs which were once confined to mainframe computers. Educational programs have been developed for use on these systems in business, the home and schools.

Previewing much of the available educational software makes it difficult to envision more than a brief life for CAI. Hofmeister (1982, p.116) notes that while improvements in cost effectiveness and reliability are obvious in hardware technology this "has not been matched in software development." Much educational software begins with a stimulating presentation followed by a sequence of tedious-to-read material. The initial enthusiasm which students exhibit when they begin working with the computer soon vanishes under the assault of poor pedagogy. Unfortunately, the necessary coordination between programmers, psychologists and educators in designing effective and motivating computer aided instruction is not usually obvious in the end product. Since traditional paper and pencil tasks can present drill and practice exercises as drably as poor computer software (Beechhold, 1982) it is difficult to justify the greater expense of CAI in an era of budget cuts and increased fiscal responsibility.

Some drill and practice educational programs have become increasingly stimulating and motivating, using visual effects much like video games, to maintain interest in presented material (Chaffin, Maxwell & Thompson, 1982). Further, CAI, through a microcomputer delivery systems, is transcending the drill and practice mold in public school classrooms. A program like LOGO affords a glimpse of an alternate to drill and practice (Muller, 1982). Designed at M.I.T., this program, with its simple authoring language, affords even the preschooler the opportunity to interact with the computer.

This article attempts to evaluate the applications which best suit the microcomputer in an educational setting. Attention will focus on adapting effective pedagogical practice to the micro's programability and delivery capabilities. To begin, let us consider the learning process as it relates to the interaction between man and machine.

## Man-machine learning

### Two Theoretical Bases

CAI programs are anchored in one of two major pedagogical philosophies. The first advocates that learning takes place in "being told". More prevalent in the 1960s, this view grew out of early programmed learning research and developed into the teaching machine programs which were to revolutionize the education process through individualization (Snelbecker, 1981). The second view holds that learning occurs "through discovery". Different from the former, the discovery view encompasses such activities as seeking out relevant from irrelevant information and information modification for error removal. Both of these activities require an information modeling ability (Howe, 1978).

The ability to create models for data to be learned is essential to storage of that data in a meaningful way for later retrieval. This means that in order to effectively assimilate information into one's experience, new material must be meaningfully related to the learner (Mayer, 1979). Examples serve to illustrate this concept of learning. Given some theoretical framework of psychology, a student can learn the underlying principles by rote memorization with more or less difficulty. The theory, however, becomes incorporated by the learner more clearly and more usably when examples are employed to explain it, giving "flesh to the skeleton". As such, the examples illustrate the manifestations that the theory takes in a less abstract form. It is contended here that the relationship of new material to the learner's experiential background facilitates the acquisition of that information (Ausubel & Fitzgerald, 1961; Gagne, 1975; Howe, 1978). Hofmeister (1982, p.117) applies this principle to conceptual teaching in educting special education pupils:

> Special education pupils are often "special" because

of their inability to learn easily from the haphazard structure of the environment. In order to teach concepts to special education populations, we need to have on hand a rich reservoir of examples and nonexamples of the concept we are teaching. These examples and nonexamples need to be carefully assembled, carefully matched, and carefully managed.

It is this awareness of what the pupil has learned, as it relates to what is being taught, that affords educators a plan by which learning can be structured.

CAI programs which implement both principles have been developed in the area of mathematics. Visual representations of abstract concepts are available in geometry, calculus, differential equations and statistics (Smith, 1981) Binary stars, longitude and latitude, and sky maps have all been illustrated using CAI visual models in college astronomy classes with success (Reitmeyer, 1983).

Hofstadter (1979) applies the notion of isomorphs to the acquisition of knowledge. Deriving his use of the word from mathematics, Hofstadter considers an isomorph in learning be "an information preserving transformation" (p. 49). Here, it serves to illustrate how meaning is attached to data in the process of learning new information and is based upon a comparison of the new data to that which the mind has previously stored. This ability of the new material to somehow be meaningfully compared to an existing form in the brain is what fosters the acquisition of new meaning. In Hofstadter's words "... it is such perceptions of isomorphisms which create meanings in the minds of people" (p. 50). In Piagetian terms the student can assimilate new information only after accomodating this information to existing schemata (Pulaski, 1971).

"Being told" and discovery learning

Being told does not rule out the acquisition of knowledge but the learner, in this posture, is more passive and, it is suggested here, less inclined to establish meaningful relationships to existing data. The phrase "drill and practice" is descriptive of how learning of this kind is accomplished. With sufficient exposure material is learned as a result of its ordering in some meaningful way as an individual interacts with the material through repeated presentations. Here, the learning situation is controlled by the computer program.

Discovery learning similarly requires an ordering, but this ordering is generated integrally as part of the learner's information seeking in relation to what has already been learned or experienced. Hands-on experiences in a classroom exemplify this teaching strategy. For example, teaching a child about seed germination takes on a different meaning when seeds are germinated in class and grown to production in a school garden. In the same way, experience stories demonstrate the effectiveness of discovery in teaching reading to young children.

In contrasting these two approaches to CAI, Weir (1981) states: "We reverse the usual relationship between computer and student that is found in a conventional computer assisted instruction. Here, the clever program teaches a 'dumb' student. In contrast, the student is required to teach this dumb computer how to carry out the task in question" (p. 77). Control, in discovery learning, originates from and is maintained by the learner.

Both methods may result in successful learning of different materials. Instrumental learning theory lends itself more to the "being told" type of CAI programs and discovery learning is best addressed by "relational teaching", that is, the goal is to have the student relate new material to information already possessed (Howe & Boulay, 1979). Let us examine some strengths and weaknesses of both approaches as CAI delivery methods.

Strengths and weaknesses

Traditionally CAI instruction has utilized the behavior modification approach in instructional design. This powerful teaching tool utilizes reinforcement to increase the frequency of selected responses (generally correct answers), in the CAI program. A correct response is rewarded in some manner, increasing the probability of more correct answers. Since the material to be mastered is designed by the instructor, successful behavior shaping is generally built upon a task analytic foundation (Mozeico, 1982). Through task analysis instruction is formulated in a well organized sequential order. Progressing in small increments, the learner builds more complex targetted skills upon simple existing ones. Appropriate reinforcement is the motivation which provides the impetus for continuance in program sequence.

The coupling of instrumental learning theory with task analysis is an effective method for teaching facts. Goal achievement is rapid when the participant is motivated and placed at an appropriate entry level. Materials to be learned can be segmented into manageable units and built upon in increments in available time segments at the student's pace. This method also serves as an enhancement to classroom instruction.

While being effective in fostering the acquisition of presented material this method depends, in large part, on discovering reinforcement which is meaningful to the learner, often not an easy task with some children. This method of CAI is teacher directed and, as such, fails to capitalize on students' inate desire to explore the environment in which they function. Children who build sand castles learn how necessary water is to give the sand the needed consistency. While that fact can be taught to a child through a programmed analysis of the components and mastery, controlled through reinforcement, it is the child's interaction with the sand, wet and dry, that will formalize this information for life. A controlled presentation of material to be learned is a fundamental learning technique within our schools. However, the "being told" method, when used in CAI does not lend itself to the development and utilization of a child's natural desire to explore as seen in the sand castles. The distinction in educational philosophy can be best characterized by two differently oriented CAI program examples.

In our first example, the instructional goal is mastery of multiplication tables using 1 to 10 as multipliers and multiplicands. This program can be effectively presented using instrumental learning theory. Correct responses can be presented initially, followed by drill in which correct responses are rewarded and incorrect responses are presented again. Once the criterion rate is achieved the program is discontinued or expanded to include more facts. Order of presentation is determined using task analysis, breaking the total task into manageable chunks, arranged in a sequence of increasing difficulty.

A program which uses the discovery approach might be designed to teach the associative property of multiplication and number constancy. In this program graphic representations of randomly generated multiplication examples are presented using the micro's graphics capability. Computation is dependent upon student-created representations using graphic squares. Instructions consist in directing the student to create various representations of multiplication facts and asking questions about the properties each construction exhibits.

It would seem that mastery of the first program will more adequately equip an elementary student to perform well on a test of multiplication facts. The second program more adequately teaches the underlying principles of multiplication and gives a visual mnemonic that will be valuable throughout the student's schooling and life. Obviously, both methods are valuable tools in teaching math skills. Yet the instrumental type of program is the standard by which many educators are evaluating the role of the computer in the classroom. While this type of learning program is available, it does not represent the teaching potential available through the use of microcomputers. Muller (1982) cites an example in which professional draftsmen and engineers were compared to students for their ability to draw odd sized angles freehand. The students had been using LOGO graphics, a discovery type program that allows students to create lines and angles using the microcomputer. When the angles of both groups were measured with a protractor the students more accurately drew the given angles.

Evaluation of Student Input

The reason that so much of the available educational programming follows the instrumental learning theory model has a lot to do with the microcomputer itself. These machines, until only recently, used the language BASIC, which more readily fits the "being told" perspective of learning. However, with the added power,of recently developed chips, yielding increased memory and faster processing, languages are being made available which permit more sophisticated CAI programming. Increased capacity permits user interaction with microcomputers in a way that resembles the powerful interaction available on the mainframe computers.

These learning programs contain a set routine of events that the program's designer has built into the instructional package. Correct input from the student results in continuance of the program and/or a reinforcement message followed by continuance of the program. In effect, the learner is being told that he is responding correctly or incorrectly, much like a teacher tells students that they are doing well or poorly. Unlike a teacher, this instructional program fails to go beyond judging the degree of correctness of the program. Its limitation consists in its inability to sample the student's knowledge and determine where the misconception that led to the incorrect response originates.

This type of programming can be thought of as "top down" in that it resembles learning from a manual in a preset sequence but without any variance from the order of presentation. And like a manual with a finite presentation, when something is not explicitly clear to the learners, they must turn to some other source to help explain the misunderstood data.

For the learner, input regarding errors consists only in the recognition that they have occurred. Thus, these programs are dependent upon the assistance of a qualified teacher who can question students to determine where their difficulties lie and what further instruction is necessary. This type of program can be a valuable practice vehicle used to reinforce classroom presentations.

The discovery type CAI programs can also be used to support classroom presented instruction. However, it is not bound by this role. From artificial intelligence, languages have developed which permit more in-depth interaction between the learner and the computer. Increases in storage capacity for the micros are necessary to support such detailed programming. Whereas the former "being told" instruction program could be described as a "top down" presentation of material to be learned, discovery type CAI is better described as a "middle out" program (Laubsch, Fischer & Bocker, 1979).

## Recursion

In order to understand "middle out" control one should be familiar with the concept of recursion. A good example of recursion might be the communication that occurs in a first grade classroom. For the teacher, trying to focus attention early in the morning on the latest office memo which includes a request to sanple student feelings, the first child who enters the classroom represents the first recursive step of the day. The teacher must put on hold completing the memo, intending to read it when an opportunity presents itself. However, the direction to sample student feelings can be implemented on this first child, whil this operation is one step away from reading the memmo. This step, too, can be punctuated by a second interruption, a call by the principal on the P.A. system. We can see that if the communication with the child is to continue we are now two steps away from the memo reading level. Needless to say, as the group of first graders increases, return to the first level becomes more remote though the memo will eventually be read and is currently being partially implemented.

Programming which is capable of recursion is able to act upon itself. In proceeding through the program a particular procedure may be required to begin again at the beginning. It is put on hold (much like the teacher when the first child came in) and the same procedure starts again at its beginning. This recursive call, now further away from the original execution of the procedure will eventually be resolved, and programming will return through the same progression to the place of the first interruption.

This resembles the course of action taken by a teacher of reading when a student is unable to tell what a particular word is. The teacher will proceed deeper into the word, asking the child to give the initial sound. If the beginning sound is known, another activity is initiated. Does the child know the rest of the components in the word? Can these components be assembled into an accurate representation of the given word? Constantly, teaching is taking place at each deeper level in an attempt to remediate the difficulties that will result in the correct pronunciation of the word at the initial level.

Errors

These same recursive levels occur in a "middle out" program. Here, errors are dealt with in a more in depth manner, much like the teacher might deal with them. If the first level of query does not yield insight into the incorrect response, another level (or another situation within the first level) is examined. This persual of the student's mistakes is the underpinning of effective CAI. In order to channel the learner through the instructional material effectively the system must be programmed in some detail with the material to be learned as well as background information. This more extensive knowledge of possible answers and probable mistakes enables the system to correct the learner (Stevens, Collins & Goldin, 1978).

It is obvious that increased microcomputer memory is essential in dealing with the myr[illegible] of potential avenues of misconception that the learner ca[illegible]. An artificial intelligence program like SOPHIE can store 300 thousand words in an effort to present a lesson that teaches students how to trace a fault in an electronic system (Brown, Burton & Bell, 1975). This information is stored in a network of logic that processes input from the student along channels that test appropriateness of the information.

Once again it is important to note that this type of program, while tremendously powerful, is still a "being told" program. How do discovery oriented programs deal with errors differently? Educators have available to them, LOGO, a program which provides interaction of a different sort. LOGO affords the user a language which permits access to the micros beginning with preschoolers. Much has been written about this program, citing examples of how moving the cursor, called a turtle, is done by the student using simple commands like forward, backward, etc. (Solomon, 1982; Thornburg, 1982). Our interest resides in how this type of program (and programming itself) deals with errors. For the young child the graphics mode is an understandable means for interacting with the program. Movement on the screen resembles and can be associated with interaction with the child's environment (Harris, 1982). If children understand right, left, forward, etc. their input (or ordering of cursor movement), if not reflecting their desired direction, immediately indicates to them the inaccuracy of their commands. Referring back to our discussion of isomorphs and meaning, a meaningful representation of their perceived reality is not preserved when the output on the screen does not represent what they had intended. The error message is simple, graphic and meaningful to preschoolers through adult.

In a Piagetian perspective control of both the environment and the technology are available to the child for exploration (Markusen, 1983). This is not the controlled environmemt of the "being told" instructional method. Yet it resembles the child's interactive environment, more like the sandbox, and fosters exploration.

<u>Programming</u>

This brings us to our final consideration of errors. The most intimate association with the micros will occur for the student (as well as teachers) in writing interesting programs. It is important to note that discovery learning which takes place in the LOGO program is not limited to that program. Authoring languages (those languages which enable creation of programs and which are often more like natural language) like BLOCKS and PILOT serve to access the microcomputer for persons who might be otherwise disinterested in mastering more complex languages (Kleiman & Humphrey, 1982; Luttner, 1981). BASIC is the language with which most microcomputers are equipped and while it is tauted as a beginning language it is not clearly understandable to many students (Papert, 1980). Therefore, those who might profit from interacting with the microcomputer do not have it available for programming skill. It is suggested here that learning to program is a powerful skill that all students should have available to them to learn.

The implementation of logic, planning, sequencing and abstract thinking as well as learning to use an alternate language, are all components of programming. This learning is available to the preschooler using the LOGO program, through college students learning more complex languages like FORTRAN, COBOL and Pascal, and to more complex artificial intelligence languages like LISP. In each example the computer's unthinking following of orders permits no mistakes by the person who is programming. In addition, its infinite patience affords the learners an environment in which to test their learned instruction. Like the "top down" programs feedback is immediate. If input is incorrect the program will not run. But in addition to this immediate feedback, learning to program provides an added incentive; successful running of the program.

Errors are called "bugs" and correcting a program is called "de-bugging". This particular exercise is taxing and requires attention to part-to-whole relationships. Just as the immersion method is highly successful in teaching a foreign language so too immersion in the creation of a program develops computer language proficiency. Errors are important learning tools which foster a more meaningful understanding of the process.

A further positive aspect for learning to program consists in the usefulness of such a skill. The languages mentioned earlier are not learned as nonfunctional exercises, but are actually implemented in the scientific and business community. Whereas an interested high school student may focus his attention on developing the newest space battle game, this end does not detract from the thinking skills necessary to create the games. Incidentally, some students have begun making money with programs they have developed on their school and home microcomputers (Solomon, 1982). Seeking reinforcement for which the student will work is no longer a problem. The expectancy of success serves as a tremendous motivator.

## Special Education Implications

In considering the increasing influx of microcomputers into the public school classrooms this article has been addressing the CAI technology and pedagogy available for this educational delivery medium. The micros are not only limited to instruction. Their role has also been to enhance compliance with Public Law 94-142 through implementation of individual educational plans, monitoring of special student academic progress and aiding in prescription (Hooper, 1981; Meure, 1982; Rizza, 1981).

Behaviorally disordered students have benefitted by the motivational and discovery aspect of micro-CAI in an Austin, Texas program ("Center Aims", 1982). This group of special needs students, along with mentally handicapped and learning disabled are populations which profit from CAI's positive experience. Because of their exceptionalities, these learners have much difficulty in dealing with school curriculums. The CAI programs allow these students to more successfully involve themselves in learning.

The mentally handicapped and learning disabled profit from repeated exposure to instructional materials in drill and practice format. Feedback is immediate and programming can, as described earlier, follows the task analysis format in incrementing instruction manageably and successfully. Authoring languages are available to the mentally handicapped, much as they are available to preschoolers, building upon concepts and skills at the individuals level of functioning.

The physically handicapped possess a limited perspective of the world, since their only contact may be from a wheelchair or in being carried about in the arms of another. Spatial relationships can be taught through discovery as well as more structured CAI programs, using the graphic capabilities of the micro (Weir, Russell & Valente, 1982). In addition, micro-CAI programs open a door to physically disabled individuals which enables them, not only to communicate with their world, but also to contribute to it in the capacity of a worker. Disabled persons desire meaning in their lives and many are capable of expressing this ability which is locked in their disabled body in the form of programming skills, data management and, even with word processing skills, clerical work. Mastering these skills through CAI tutorial programs can permit disabled individuals to function in society which liberates them from a position of total dependence.

Of interest in CAI is the work being done with learning disabled students. Many of these children have found the discovery programs enjoyable experiences in which their intellectual ability becomes apparent. Whereas normal children can master instructional material rather easily, learning disabled children are described by a marked discrepancy between their intellectual ability and their performance.

Four major components of CAI assist these children in performing more adequately in the academic area. To begin, CAI programs are infinitely patient teachers (Howe, 1981) and, unless programmed otherwise, are emotionally neutral. This can be immensely important to a child who has endured being the slowest in the class for any period of time.

The second aspect that CAI makes available to learning disabled children is repetition. In the form of drill and practice, mastery can be insured through continual presentation in a stimulating format. Watkins and Webb (1981) have compared the performance of CAI and non-CAI taught, learning disabled students on arithmetic performance. CAI tutored students performed significantly better on the arithmetic post-test.

The third reason that learning disabled students (and indeed, all students) benefit from CAI is evident in their desire to get to the terminals. The success these students can be guaranteed in mastering skills, as well as the stimulating visual appeal of the system and immediate feedback, all serve to maintain a high degree of motivation for students. Whereas other systems have lost their interest the positive involvement students experience in CAI seems to maintain a high degree of motivation. It has been this teacher's experience that even young preschoolers become immediately interested in manipulating the cursor with the keyboard. However, only time will tell if micros, and CAI in particular, will retain the student's interest.

The final aspect of CAI which meets the learning disabled child's needs in a unique way is its suitability to discovery learning (Schiffman, Tobin & Buchanan, 1982). This article has discussed the graphic capabilities of programs like LOGO to present position in space to learners and has stressed the positive impact of learning a programming language like BASIC as a means toward developing planning, computation skills and language mastery. All of these discoveries are available to the learning disabled child. Simulations also afford real world learning involvement that enables subjects like history, science and geography to become personally meaningful to these students.

The learning disabled child is characterized by many deficits which go beyond the scope of this paper. However, these children are most aptly described by their failure in the existing school program. It is suggested here that involvement with the learning environment in a format which insures success, reflects reality and provides motivation will enhance the performance of these children. CAI affords this opportunity. It is further suggested that a subject for research is to examine some form of "head start" in cognitive development using the discovery programs available in CAI, as well as remedial program evaluation for learning disabled and mentally handicapped individuals.

## Education's Responsibility

In the beginning of this paper the positive and negative attitudes exhibited by teachers toward computers in the classroom were mentioned. It should be clear that the position taken here is in support of increased use of CAI both in "being told" and discovery type learning, including programminging skills. Elementary school students who have had access to computers in the early grades have demonstrated ability to solve complex physics, p 'siology and geometry problems (Molnar, 1979). Society is increasingly using the computer. Since children are able to become familiar with the computer while successfully mastering instructional material it becomes incumbent upon school districts to employ this technology. The current laissez-faire attitude that persists in this area is allowing other nations to develop programs and technology that will, in time, surpass our own (Molnar, 1977).

The educator's role is twofold in implementing CAI. First, teachers need to become familiar with programs that teach effectively. We have already described those that fail to do so. And secondly, teachers need to understand programm_ng as well as be able to create programs. Too much poor pedagogy has been evident in the available software. Educators are needed desperately to create and participate in the creation of CAI material that guarantees superior instruction. Leaving this task to the booksellers and non-educators will be reflected in the less than quality instruction that is possible.

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