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AUTHOR	Bell, Frederick H.
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ABSTRACT

Computers can effectively promote learning, but only if they are used in ways which are consistent with the natural processes of learning. The analysis of several computer-assisted instructional (CAI) projects reveals that computer-related learning environments are most successful when they closely resemble the natural learning environment found in the non-school world, thereby capitalizing on the student's inherent motivation to learn. This suggests that educators should adhere to the following principles when utilizing computers. First, the computer-related learning environment should be interactive and subject to learner control, thus permitting creativity. This means that students will help plan lessons, define problems and solutions, use tests as learning experiences, and judge their own success. Secondly, students must be given the opportunity to make things work--to write and debug computer programs, for example--and should receive realistic recognition and rewards according to their degrees of success. Finally, students whould be encouraged to share what they have learned to do well by teaching it to others. (LB)

Catalyzing Creativity in Computer-Related Learning Environments

Frederick H. Bell
2310 Cathedral of Learning
University of Pittsburgh
Pittsburgh, PA 15260

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In view of the evidence gathered by thousands of people in hundreds of studies designed to test the effectiveness of instruction and learning in computer-related settings, it is not inappropriate to state that computers can be and are being used quite effectively to promote learning. Although many articles have been written in support of the use of computers in instruction, the question of why computer-related instruction can be so effective is still a relatively open issue. This paper will suggest several reasons for the successful use of computers in education and will present principles and procedures for catalyzing creativity in computer-related learning environments. These principles and procedures emerged from six research and development projects to study educational applications of computers.[1] Table 1 contains a list of the projects together with a description of the major activities of each one.

[1] Additional information on each project is available from the author.

PROJECT (Funding)	PARTICIPANTS	ACTIVITIES
Computer-Augmented Calculus (Cornell University) 1967-69	120 college students	A computer-augmented calculus curriculum was developed and tested in a college course.
PRISE (National Science Foundation) 1971-73	30 college professors	The participants learned how to use computers, developed curricula, and were organized into an educational computing network in Pennsylvania.
SOLO (National Science Foundation) 1970-73	High school teachers and their students	Teachers learned to use computers in teaching, and assisted project staff in developing computer-related curriculum modules.
SOLO WORKS (National Science Foundation) 1973-	High school teachers and students	Advanced computer-related laboratory devices are being developed to help high school kids learn mathematics.
Computers in Education (None) 1971-74	Pre- and in-service high school teachers	Two university courses in educational uses of computers were developed.
CATALYST (University of Pittsburgh Alumni) 1973-	Student Teachers, teachers, doctoral students, and high school kids	A model for training university professors, high school teachers, and students in modes of learner-controlled educational computing is being developed.

TABLE 1

It appears that the explanation for the success of computer-related instruction is to be found in the nature of learning. Why do some people learn well in school while others fail? Why are some people motivated to learn, while others appear to be motivated not to learn? A comparison of the factors that cause a person to be an effective learner while he is outside of school to those factors which cause the same person to be a very ineffective learner in school sheds some light on the reasons and motivations for learning in school. Intellectual development and learning are natural processes, which occur spontaneously in a normal environment, just as is physical growth. For most pre-school children and for most school children after school, the normal environment is one in which a significant proportion of learning occurs through relatively free movement and interaction with a variety of natural and man-made things. The school environment, which many children (especially poor students) view as being a subnormal environment, is one that permits very restricted movement and interaction and that has few interesting activities for children. For a dramatic illustration of this fact, read "The Poor Scholar's Soliloquy."[2]

An effective way to promote above normal physical development is to create an above normal nutritional environment. Similarly, if school is to be an effective learning environment, it must be as rich in a number of significant aspects as is each child's non-school environment. Consequently, the key factor for improving learning is improving the learning environment. This is not to raise the specter of environment versus heredity and to imply that environment is the winner in a battle for dominence. The fact is that teachers can not control their students' heredities; however, they do control a significant proportion of each student's environment.

What about motivation and learning? Nearly everyone is born with the motivation to learn; survival depends upon it! For many children school is an environment in which their natural motivation to learn is under constant attack, so much so that they lose much of their motivation to learn things in school. Fortunately for these children, half of each waking day is spent outside of school; so they can still learn a plethora of necessary and useful things. For these kids, and for their teachers, attempts to motivate them to learn in school are attempts at curing a disease which was created by the school. It's analogous to a doctor in a hospital attempting to transplant a kidney in a patient several years after his own healthy kidney was removed by other doctors. A child can survive in a deficient learning environment, but he will certainly be handicapped in achieving his potential. Any teacher whose students leave her classes with the same amount of motivation as they entered with can be labeled a success. If a teacher can increase her students' natural desire to learn, she is truly an outstanding teacher.

Countless attempts (many very small and inexpensive, some very large and quite expensive) have been made to change the schools and to change teaching methods. Computer-related learning in schools also will add to the cost of education; however, it has had many successes and promises to have even more dramatic successes. Is there sufficient justification to promote computer-related instruction and learning in the schools when many innovations such as programmed instruction, teaching machines, televised courses, and a number of other curriculum modifications either have failed or have been little better than the old

[2]Author unknown. "The Poor Scholar's Soliloquy," Childhood Education, XX (January, 1944) pp. 219-229.

methods which they replaced? For example, some people feel that "new math" in the schools has been a failure; others view it as being little, if any, better than the "old math" curricula which it replaced. Whatever one's opinion of the merits of "new math", its development and implementation in the schools certainly cost a large number of dollars. Have current results and will future results justify the large expenditures necessary for implementing computer-related learning in the schools? Can one really expect computer-related learning to succeed where other technology-based innovations have failed? The answer to each of these questions is yes; computer-related learning is effective and does justify its expense. If students are given significant control over the computer and other learning hardware in computer-oriented learning environments, they will perceive computer-oriented environments as being quite different from the traditional school environment; that is, classrooms arranged to accommodate lectures, demonstrations, and discipline. However, a different environment is not necessarily an improved environment. A properly constructed, student-controlled computer-related learning environment is a positive learning environment, because students can move within the classroom and can interact with a variety of interesting learning options (even in an artificial, school-based environment) in a manner similar to the way they learn in a good non-school environment. In addition the rewards and other positive factors which influence people to learn and work in computer-related environments are similar to the same positive factors which operate outside of school.

What are the positive factors, many of which are not usually found in school but are present in computer-related learning environments, that motivate people to learn? Several of the most significant factors are the rewards and satisfactions found in creating things, in making things work, and in receiving recognition for activities and accomplishments. It is a fact that there are mechanisms in schools that permit kids to be creative, to make things work, and to receive rewards. However, too often students must create what the schools want and make things work in the required way. The procedures and outcomes are completely specified, and success can be determined only by looking in the answer book or by asking the teacher. In addition, many school rewards are both artificial and superficial. One might speculate about the rewards expected by people who voluntarily write journal articles such as this one. Whatever the expected rewards, it is doubtful that such efforts would be expended voluntarily if authors received only an "A" and a gold star attached to their manuscript by the editor.

When students are permitted (even required) to select their own problems to solve, to phrase problems in terms amenable to attack, to select their own plan of attack, to make appropriate modifications when things go wrong, to decide if the answer is correct, and if they are rewarded by the satisfaction of an interesting and difficult task well done; there will be no problem of motivation to worry the teacher who will be an equal and respected partner and resource person in the learning team. Teaching and learning will become synonymous terms, as they should be. Such a learning situation is not utopian; students and teachers can and do function effectively in many student-controlled, computer-related learning environments. The following examples selected from many observed in the projects listed in Table 1 illustrate some of the improvements in learning and teaching which can take place in computer-related learning environments.

Testing should be a learning experience; however, in practice most testing is done for the purpose of evaluation, with a high grade being the only reward for student achievement. Computer-based testing can turn testing into somewhat of a learning experience by permitting a student to test his own learning by taking several versions of a computer generated test until he is satisfied with his own knowledge. The computer can generate thousands of versions of a single test, each student can take as many practice versions as he wants, and the teacher need not waste time with tedious test scoring. The computer can score each test and, if a grade is needed, each student can indicate at the beginning of the test that he is ready to have his results on this version used for a grade. Testing can also be an effective learning activity when students evaluate their own test results by working in small groups to decide upon correct answers while using textbooks, references, each other, and the teacher as sources of information. A constructive method for testing knowledge and understanding of mathematics algorithms and skills is for kids to prepare and execute computer programs to solve problems. Let the computer do the busy work; if a person can teach a computer how to solve a problem, he certainly understands the procedures and concepts. It's not necessary to rely on the teacher's opinion concerning right and wrong. An incorrect program won't run, and the learner is forced to analyze his problem solving procedures and to correct his errors. The informal, professional atmosphere of a computer-related learning environment quickly replaces the incentive to learn through fear of failure with learning for the purpose of doing interesting tasks and getting things to work. Tests should be used in a variety of modes to evaluate learning, and not as ends in themselves. The ultimate test result is success in getting the job done.

When evaluating the effectiveness of computer-related learning environments, the opinions and comments of students are necessary for planning modifications. Students should be accepted as equal partners in preparing and evaluating new methods, and should not be treated as subjects who are being used in an experiment. When evaluating new procedures each data collection session should be an interesting learning situation for the students and teachers, as well as for the project staff. For example, an opinion questionnaire was designed as a flow chart and given to seventh grade kids as part of a lesson on planning and flow charting. The questionnaire gave them practice in reading and interpreting flow charts, and the project staff obtained the information which was needed for proper evaluation.

Rewards and recognition should be dispensed according to real standards of professional excellence and utility. Recognition of a significant achievement of one student by another student who is an expert in that area provides much more incentive than does praise from a teacher who may have many academic credentials but who doesn't understand the value of the achievement. In addition to the inner satisfaction of creating a good piece of work, examples can be cited of students and teachers who produced materials and ideas resulting in professional recognition and monetary rewards. Many of the students, teachers, and college instructors participating in our computer-related environments and freed from the artificial restraints of typical classrooms have produced significant work and have received recognition for their efforts. Students and teachers have authored textbooks, articles, and curriculum materials and have improved their professional stature. Students recognize the difference between real recognition and artificial school rewards. The pleasure and motivation of students whose work was good enough to merit inclusion in the computer center's public program library, to be part of a book or article, or to be used by other students and teachers certainly exceeded their pleasure in having an A placed on their work by a teacher.

Computer-related learning activities have shown that immediate feedback in a teacher administered testing or drill and practice session can inhibit the development of learning skills. Teacher centered learning and evaluation can retard the development of independence and creativity in the learner, while promoting the school as being the only place to learn. Many people graduate from schools and colleges with the mistaken impression that the best or only way to learn something new is to take a course in it. Writing and debugging computer programs to solve interesting problems can give a student a great deal of insight into real-world problem solving and assist him in learning about the nature of learning. Developing and using advanced computer-related laboratory devices highlight one reason why much school-based education is irrelevant for the problems found in many occupations. Textbook problems usually are precisely stated and have one exact solution; whereas real-world problems seldom are well-defined, and usually have a number of inexact solutions. In addition, anyone who writes computer programs for solving problems quickly learns that the difficult part of solving a problem is stating the problem precisely; poorly defined and stated problems usually can't be solved.

A most important principle that must be heeded if computer-related learning is to be improved learning is a corollary to the principle that effective learning dictates learner control of the learning environment. The principle can be stated: if computer-related learning is to be effective, each learner must be given considerable control of the computer and related hardware, software, and courseware. Although traditional computer-assisted instruction has its uses, it also has its limitations. Computer-assisted instruction is done in a mode whereby the computer program controls the learner and his learning, which differs from human teacher control only in the fact that a human teacher can be more flexible and can interact more effectively with each student than can a computer program. If computer-related learning is to be significantly more effective than other technologically-oriented learning modes, it must be designed and structured so that the learner has control of the learning system.

There is no particular magic about computers which makes them more effective learning devices than many other innovations that failed. It is probable that any modification of the learning environment which is perceived by the learner as being different (in a good sense) and which permits him to learn in modes similar to those that he uses outside of school in the "real world" would be quite effective in improving learning. For the kid who is "turned off" by school, changing the content, style and design of the textbook, assigning different problems, and presenting material in a different way is as meaningless as replacing a brown iron fence with a red steel fence--the fence is still there. Computer-related learning environments catalyze people to do outstanding work; because they provide a setting in which each student can create things, make things work (a computer, for example), obtain real recognition for work which is done well, and have an opportunity to teach others how to do those things which he has learned to do well.

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ERIC Information Analysis Center for Science, Mathematics and Environmental Education
The Ohio State University
Columbus, OH 43210