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ABSTRACT

The computer-centered, interdisciplinary learning environment called Soloworks at the University of Pittsburgh is described and placed in the perspective of continuing curriclulm change. The organization of the hardware into computer lab, dynamics lab, synthesis lab, modeling/simulation lab and logical design lab is explained. Teaching/learning innovations growing from the project are summarized; steps toward developing a secondary school curriculum are discussed. The project and related developments are said to make possible and practical a truly interdisciplinary and revolutionary approach to formal education. (SK)

Computer-related Laboratories: An Inter-disciplinary Approach to Learning

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FACTORS INFLUENCING CURRICULUM CHANGE: AN HISTORICAL PERSPECTIVE

In the years following World War II a number of diverse forces converged in a manner that made general curriculum reform inevitable in schools in the United States. A backlog of criticisms of the educational system had been building before and during the war, and at the conclusion of the war resources were released which made major and expensive changes in teaching methods and curricula possible. World War II with its development of and reliance upon complex weapons such as rockets, radar, and nuclear bombs showed that the ability of a country to wage war was now closely related to the quality of its science and technology. The necessity for rapid training of large numbers of men and women in technological skills required for the war effort highlighted the inadequate scientific education that was being provided by the educational system. There appeared to be a concensus that the first and most important step in guaranteeing a reservoir of scientific personnel for the future was to increase the emphasis on science and mathematics in the public schools and to improve the teaching of these subjects. Dramatic post-war changes in society and the need to reconstruct a large portion of the world which had been destroyed by war reinforced the viewpoint that what was being taught in schools needed to be modified.

The war years, and even prewar years, witnessed a declining enrollment in colleges. In attempts to reverse this trend many colleges relaxed or eliminated admission requirements following the war. However, while easing entrance requirements, many college programs and courses set prerequisites in mathematics and science which were difficult for traditionally educated high school graduates to meet. An increasing emphasis in society on the value of a college education together with postwar economic prosperity resulted in an influx of students into colleges. Many of these students had been poorly trained in mathematics and science in high school which caused additional pressures for curriculum reform. These factors together with labor shortages, the increased prestige of the sciences, and a new concern about preparing students for college made the revolution in the school curriculum inevitable.

To respond to these concerns about the quality of education in the schools, prestigious scientific and education organizations initiated a series of conferences and reports about education and the needs of society. In 1947 the Commission on Post War Plans of the National Council of Teachers of Mathematics called for new goals and methods for mathematics teaching and urged a comprehensive curriculum reform in school mathematics. In 1948

the Symposium on College Entrance Requirements sponsored by the Mathematical Association of America called for a reform in high school mathematics which would substitute newer, more interesting, and more useful mathematics for outmoded topics in the curriculum. The Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science issued a report in 1947 calling for a new emphasis on mathematics and science in high schools to meet the scientific demands of postwar society.

At the time pressure was mounting to make the school curriculum modern and relevant, new theories and research on how people learn were beginning to discredit some of the traditional methods of teaching such as lecture, drill, and memorization. The theories and research of the Swiss psychologist and biologist Jean Piaget and his followers indicated that traditional teaching methods should be modified according to various age, heredity, and environmental related stages of intellectual development in children. Research conducted by J. P. Guilford and his colleagues into the factors comprising intelligence showed that general intelligence is a combination of many specific intellectual abilities. Consequently, different methods of presenting information (concrete versus abstract, or figural versus symbolic illustrations) may be appropriate for various people. Another learning theorist, Robert Gagné, developed and tested his theory that knowledge is organized hierarchically in the mind and that lower level skills and principles must be learned before higher order structures can be understood. Jerome Bruner, a learning psychologist, thought that transfer of one learning task to other learning tasks can be achieved through appropriate teaching and that people can be taught to "learn how to learn." Another psychologist, David Ausubel, said that verbal exposition (carefully presented lectures) and appropriately structured problem-solving experience is the most effective general method to use in teaching high-school students. B. F. Skinner and others have studied the effectiveness of various stimuli and responses upon learning and the effects of rewards and punishments upon learning. While these diverse (and sometimes contradictory) learning theories seemed to indicate that there is no best way to teach, they did result in the realization that different people learn in different ways under different conditions. The applications of these theories have been apparent in the new school curricula, and have greatly influenced both the organization and structure of high-school textbooks and procedures for teaching. Such common new methods for teaching as individualized instruction, discovery learning, spiral approaches, mathematics laboratories, and computer-based instruction have their beginnings in the theories of these well-known psychologists.

THE NEW SCHOOL CURRICULUM

By 1975 most school subjects had undergone significant curriculum revision as a consequence of a number of curriculum development projects. There is the new math curriculum, a modern science program of studies, a new approach to the study of history, etc. Most of these new curricula have now been in use in schools for at least five years and evaluations of their effectiveness range from complete failure to modest success. Even most people who accept the more optimistic assessments of the new

curricula agree that there is an element of disappointment in the failure of these programs to achieve the rather ambitious goals of creating a revolution in education. Many students still graduate from school with the inability to read, a lack of basic arithmetic skills, and little understanding of the techniques and principles of science and technology. Also, student scores on some nationally administered standardized tests have declined.

Many of us who have been creating and implementing computer-related applications in our several disciplines are even more discouraged by the failure of the new curricula to exploit computer technology in teaching and learning. Even though some school curriculum development projects have produced "computer literacy" supplements, and some modern textbooks do include a few computer-oriented problems at chapter ends, and there are a few excellent (usually paperbound) computer-oriented supplements for several high school courses; computer-related learning has yet to be admitted to the main-stream of the formal educational system. The fact that most out-of-school learning is interdisciplinary in nature, as are most significant real-world problems, suggested to some curriculum developers the value of interdisciplinary approaches to the secondary school curriculum. For various reasons most attempts at interdisciplinary approaches did not work in secondary schools, and neither did intradisciplinary approaches. Many teachers are educated to teach in a single field of study and have applied their education to teaching in that field or in one area of a single subject. The team teaching approach to interdisciplinary learning was not very successful because it usually resulted in each team teacher teaching his or her specialty with little teacher interaction around content and a lot of interaction around process. The interdisciplinary textbooks usually emphasized their authors' primary fields, with a few topics or chapters included for the benefit of the "second" field. Even most intradisciplinary textbooks such as algebra and trigonometry, plane and solid geometry, etc., kept the several areas of mathematics segregated both by section and chapter, or gave preferential treatment to one area. The physical facilities of most schools had been designed for a segregated approach to teaching various subjects, and an administrative organization by departments further hindered a true interdisciplinary approach to teaching. Even where schools were designed to provide for interdisciplinary approaches through specially designed physical facilities and administrative models, the traditional methods of instruction still suggested to students that the most efficient way to learn was by separating content into subjects.

PROSPECTS FOR ADDITIONAL CURRICULUM CHANGE

Where do we stand with respect to new national efforts at curriculum reform? First, the well-publicized criticisms of our educational system combined with the effects of inflation and public demand for new services indicates that education no longer will be a "growth industry." Second, Congress has shown that it is now inclined to take a much closer look at the kinds of curriculum projects which it is appropriating money for; and that it expects rapid curriculum development, wide dissemination, and good results based upon empirical evidence. Third, the shrinking market for teachers and professors is causing these professionals to focus their

attention upon economic matters and job security. While the effect of this new insecurity among teaching professionals is not yet clear, it does appear that (for good or bad) education will be treated more and more as a corporate business and teachers will be treated as employees of that business.

Where do we now stand with respect to computer-related instruction and interdisciplinary approaches to learning? First, it seems likely that the factors mentioned in the previous paragraph will have a negative influence upon obtaining the funds needed for developing and implementing another "new" curriculum for our schools. Second, what we have now learned about the effects of the various modes of computer-related instruction upon learning (both the cognitive and affective aspects of learning) strongly suggests that computer-related technology may be the one practical tool for achieving what the curriculum developers of the nineteen sixties failed to achieve; that is, a real and positive revolution in education. After approximately fifteen years of research and development of hardware, software, and courseware for computer-related instruction, we have gathered a vast amount of information attesting to the significant results which can be achieved through this mode of learning. The really significant applications of computer technology to education appear to lie near the end of the computer-related learning spectrum, which has come to be called student control; that is, real and significant student control. And as an extra bonus, significant student control of a computer-centered learning environment such as Soloworks created by Tom Dwyer at the University of Pittsburgh automatically turns both teachers and students into interdisciplinary learners which really should not surprise us. Look at the key people who have helped develop the world of computer-related learning. Most of these people epitomize the interdisciplinary person; and all of the labels learning theorist, scientist, psychologist, mathematician, computer scientist, engineer, technologist, and social scientist can be applied to many of them. The composite, global computer-centered learning environment that has been created by these people is truly an interdisciplinary approach to teaching and learning.

With respect to an important end product of curriculum development -- the textbook -- we have come full circle in computer-related learning. First we found a need to produce a variety of computer-oriented curriculum units, modules, and books to supplement the standard, albeit modern, school curriculum. Those of us who spend part of our time at Soloworks have discovered that we now need to produce a good mathematics textbook (and probably some books in other fields) to supplement our diverse stock of computer-oriented learning modules. Furthermore, these supplements will have to be interdisciplinary in nature. At Soloworks all of our staff, our teachers, and (most important!) our students have been forced (with little pain, and hardly realizing it) to become semi-specialists in fields new to them in order to learn and to do those interesting and useful things that happen in a learning environment centered around computers and related technology.

SOLOWORKS: AN EXAMPLE OF A COMPUTER-CENTERED INTERDISCIPLINARY LEARNING ENVIRONMENT

One of the larger and more influential examples of a computer-centered, interdisciplinary learning environment in which students have significant control of their own learning is Soloworks at the University of Pittsburgh. Soloworks is both a philosophy of computer applications in education and a physical, computer-centered, experimental learning laboratory. The Soloworks concept grew out of Project Solo which was "an experimental program concerned with exploring the potential of computers in the hands of high school teachers and students" in three large public schools in Pittsburgh, Pennsylvania. The official name of Soloworks, which is supported in part by the National Science Foundation, is "A Computer-Based High School Mathematics Laboratory." In addition to its director, Tom Dwyer, and its staff, Soloworks includes high school teachers, students, mathematics educators, and others. While Soloworks is an experimental laboratory, it is also a small, informal, part-time school whose students come on a voluntary basis after regular school hours and during summer vacations. Since everyone at Soloworks is both a teacher and a student, it is difficult for a visitor to determine who is on the Soloworks' staff and who is there as an "official" student. Age and dress provide few clues, and in fact nearly everyone (student and staff member) at Soloworks has his or her own specialty and is the authority on that specialty -- at least temporarily until someone else becomes a better expert. No "subjects" are "taught" at Soloworks, but it isn't long before the newcomer to this rich educational environment starts learning about computers, mathematics, science, technology, flying, music, and even other subjects in a truly interdisciplinary fashion. Of course everyone learns how to use the University of Pittsburgh's DEC System 10 computer system and the Solowork's PDP-11/40 computer; however there aren't any "courses" in computer programming. Programming is learned by reading the manuals, by asking around, and by doing. In addition to computers, teletypes, and Cathode Ray Tube terminals, Soloworks has an airplane flight simulator, a "player" pipe organ, a plotter, a Megatek controller, TV cameras and monitors, oscilloscopes, a lunar landing simulation, a turtle, a "rabbit" (which is a big, powerful turtle and more), an art and photography lab, Rube Goldberg machines, an electronics shop, and (of course) lots of books and magazines. In fact, Soloworks appears to be somewhat of a mess -- a well-organized, well-structured mess.

The physical hardware part of Soloworks is organized around several important concepts and methods from the sciences and applied mathematics. These concepts and methods motivate a number of Soloworks laboratories. First of all there is the <u>Computer Lab</u> which focuses upon processes in mathematics and science which can be described using algorithms. In fact, Soloworks has produced a large number of printed curriculum modules illustrating significant computer applications to learning mathematics and science. Second, there is a <u>Dynamics Lab</u> which includes continuous physical processes which occur in time; for example, airplane navigation and space exploration. Third, there is a <u>Synthesis Lab</u> where very complex effects are produced by combining simple effects. The music laboratory and a six-screen, audio/visual multi-media show illustrate the concept of synthesis.

The fourth concept of modeling and simulation uses mathematics to create new models of physical reality and conceptual models of unreal worlds having strange physical properties. The lunar lander simulator is an example of the Modeling/Simulation Lab. The fifth lab, Logical Design Lab grew out of the "electronic wizardry" needed to create the other labs. Modern algebraic structures are involved in using analog and digital circuit modules to create interesting components for the other labs. None of these laboratories are fixed and static. Each one is continually evolving through addition and deletion of components, and the several laboratories are in a state of continual modification and improvement.

In addition to the positive learning environment created at Soloworks, where learning is centered around significant applications of computer technology and interdisciplinary approaches, there are several more subtle teaching/learning innovations taking place. While general learning objectives are specified, there is no single method for achieving each objective. As students and teachers (at Soloworks these two labels are nearly synonomous) work toward their main objectives, a number of unexpected, but important, secondary learning objectives usually materialize. Learning is not a neat, orderly, linear sequence of well-defined steps toward a performance objective; rather it is a somewhat disorderly, rambling sequence toward a set of objectives -- some which are well defined and others which are not well defined. Few of the laboratory devices are fixed and unchanging and there are few "laboratory manuals." The few "laboratory manuals" which do exist were produced by students, teachers, and project staff and may be partly word-of-mouth and partly printed; and these are being modified as the laboratories evolve. This is not to say that Soloworks has no "givens." Certainly, if nothing is fixed and structured, chaos would probably result; however if too much is completely specified and structured, boredom is the consequence. Soloworks has taken some significant steps toward developing part of a secondary school curriculum which has a basic fixed foundation from which a rich variety of goals and activities can be generated.

In conclusion, it appears that the computer technology and related teaching/learning strategies now exist so that a truly interdisciplinary and revolutionary approach to formal education is both possible and practical. The physical and conceptual products of projects and groups such as Soloworks, TICCIT, PLATO, HumRRO, and many others could provide a solution to some of the serious problems in our educational system.