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ABSTRACT

This bulletin focuses on the role of computer-assisted instruction (CAI) in environmental education programs. The utility of this approach in helping students learn in the cognitive, affective, and/or psychomotor domains is examined and its effectiveness is compared to other instructional devices and methods. Major topics are organized and explained under 10 specific question headings. These are: (1) why computerized instruction?; (2) why computerized simulation?; (3) why simulate?; (4) why time-sharing?; (5) what materials became available?; (6) are energy-related CAI programs available?; (7) what are multi-user computer simulations?; (8) what are the impacts of microcomputers?; (9) have CAI materials proliferated?; and (10) what does research say? An extensive reference list is included (with ED numbers for documents in ERIC). (ML)

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Using Computers For Environmental Education

Editor's Comments

This issue of the information bulletin series produced by the ERIC Clearinghouse for Science, Mathematics and Environmental Education was prepared by Dr. John F. Disinger, Associate Director for Environmental Education, with the assistance of Dr. Rosanne W. Fortner, Assistant Professor of Environmental Education, School of Natural Resources, The Ohio State University. Papers by Conrath and Mayer (1985), Helgeson (1982), and Schar (1983) were used for background material. In many cases, ERIC abstracts published in *Current Index to Journals in Education* (CIJE) or *Resources in Education* (RIE) provided the bases for descriptions of specific instructional materials. Readers wishing copies of these materials should check their availability in the appropriate issues of CIJE or RIE. Documents available from the ERIC Document Reproduction Services should be ordered from EDRS, P.O. Box 190, Arlington, VA 22210, using the order forms found in each issue of RIE.

New and developing technologies continually challenge teachers—how can these unfamiliar tools be used to do a more effective job of teaching whatever it is that we teach? Or, what can be taught by the use of this tool which we have been unable to teach before?

One challenge to the teacher is in learning to use the technology itself, is it best treated as a "black box," or does it demand both practical and theoretical mastery? Another is an extension of this. what is the teacher's responsibility, in both the practical and ethical senses, in teaching students to develop competence with the new technology, both for immediate need and for longer-range purposes?

This bulletin focuses primarily on a third aspect, arguably most important to the teacher in a specific field: how useful is this technology in helping students learn, in the cognitive, affective, and/or psychomotor domains, that which would or should be learned in some other manner if the technology in question were not available? If it appears to be useful, what is the advantage, if any, of the new technology, when compared to other available instructional devices and methods?

In terms of instructional context, the discussion below is limited to environmental education in its various facets. The particular technology addressed is that of computers. What is commonly called "computer-assisted instruction" (CAI) is of primary concern here; "computer-managed instruction" (CMI), which deals with concerns such as measurement and evaluation of instruction (Wagner, 1983) and management of records such as student absenteeism and grade files (Mandell, 1982) is at most a peripheral part of this discussion.

Why Computerized Instruction?

The earliest uses of computers in educational settings were much the same as in many other areas—record-keeping, scheduling, and other aspects of administrative support. Through the early 1970s computers were large and in effect prohibitively expensive, which severely limited their instructional uses. Mills (1984, p. 152) has pointed out that three forms of computerized instruction have developed. drill and practice, tutorial, and simulation. Of them, the continually popular technique of simulation, role-playing and otherwise, early on became associated with computer usage because of the data-handling capabilities of early computers.

It is important to remember that gaming and simulation are instructional techniques in themselves, whether computer-associated or not. A substantial history and literature have been developed in the area. For the environmental educator, the attraction of simulation, particularly of the role-play variety, is that it at least attempts to involve participants in situations which approach those of the real world, because environmental concerns are in fact real-world concerns.

The role of the computer in simulation is, as suggested above, that of a data processor. Generally, non-computer simulations are limited in their capabilities with respect to data management; thus, the involvement of the computer can add a dimension of reality, or an approach to reality, as it enhances opportunities to deal with real, or perhaps realistic, data.

Why Computerized Simulation?

In 1966, the U.S. Public Health Service awarded a grant to the University of Southern California to develop a role-playing, computer-supported simulation in support of its Air Pollution Control Institute curriculum, for the purpose of training administrators of the Federal Clean Air Act. "It was felt that student comprehension would be significantly increased by the opportunity to relate course material to vital, changing circumstances, and to test the probable effects of alternative administrative decisions on typical problems through the simulation exercise" (James, 1977, p. 184). The project was named COMEX (**Com**puter **Ex**ercise).

The first product developed under this grant was COMEXOPOLIS, a modification of Duke's (1964) computerized urban planning game, METROPOLIS. The modification incorporated air pollution subject material into the context of an urban-oriented man-machine simulation. In 1969, the COMEX project cooperated with the Environmental Simulation Laboratory at The University of Michigan in the development of the APEX simulation-game (**A**ir **P**ollution **Ex**ercise).

> APEX evolved into a computerized gaming simulation which included two main components, a simulated environment and certain gamed roles each with several subparts and the essential links which tie the system together. In APEX, the key simulation is a metropolitan area with data and models representing the physical environment, which includes both the public and private sectors. Within this model environment are the gamed roles. The two parts are linked together by computer printout which represents both the inputs of the participants' decisions as well as the simulated environment (U.S. Environmental Protection Agency, 1974 p. 33).

As originally designed, the APEX and similar simulations required large, mainframe computers. From 18 to 75 individuals can participate in this simulation, normally, a minimum of five four-hour sessions is recommended for meaningful learning. Each participant (or, depending on the number of participants, each group of participants) takes the part of a community decision-maker in the public sector (city council, county supervisor, environmental management specialist, regional planner, etc.) or in the private sector (industrialist, developer) and makes decisions while responding to situations which, it is hoped, are realistic; each session represents one year. Decisions made by individuals or by teams may or may not be compatible with one another; the computer's task is to evaluate how these decisions interact with one another and an extensive "factual" data base then predict probable outcomes. An intriguing feature is that, as participants progress from session to session (i.e., from "year" to "year"), they must deal increasingly with situations created by their own decisions and those of their co-participants. The APEX simulation has been used for college and university studies and as a training device for professionals in environmental management areas.

Another computer-assisted simulation model designed to be used in the study of complex "real-world" interactions and associated consequences of public and private decision-making is the CITY model (House, 1970). In a manner similar to that of APEX, the CITY model involves its participants in the management of a simulated city. In the CITY III version, from 30 to 200 participants play roles in "running" one of five cities with populations ranging from 10,000 to 1,500,000. Yet another large-scale computer simulation is the River Basin Model (Envirometrics, 1971).

In these and similar large-scale, mainframe computer simulations, the participants themselves need have no direct contact with the computer. In fact, it is pedagogically best that they do not, since the input of all participants is needed **before** the computer analyzes the data. Thus, participants must make their decisions advisedly, because they will have to "live" with them (in a simulated sense, of course) for at least a year (i.e., one session). Thus, the function of the computer is to process large quantities of data for the use of participants as they function in their roles of community decision-makers. The data themselves are generated by the same participants in response to situations prescribed by the simulation in terms of its baseline data.

Why Simulate?

The APEX, CITY, and River Basin Models are in fact textbook-style examples of why those involved in environmental education make frequent use of simulations. All are dynamic models; their dynamic qualities allow for the incorporation of processes, enabling the introduction and manipulation of alternative courses of action. As stated by McLean (1973, p. 376):

> Simulation-game models are excellent vehicles to demonstrate the interrelationships between interdisciplinary environmental concepts. Such models actively involve children and develop positive and logical attitudes on the causes and effects of misuse of the environmental system.

Direct experience is generally accepted as the best learning device, but the complexities of environmental concerns are such that direct learning is frequently not possible. For one thing, there may be too much riding on an unknown or poorly understood process to allow manipulation of real-world variables in real-world situations. In the same vein, the learner's lack of experience makes it difficult to allow him or her real-world decision-making opportunities. Thus, the rationale for using simulations in educational setting is based on the assumption that they are good alternatives for direct experience (Bork and Franklin, 1979, p. 17). A more extensive list of reasons why direct experiences cannot always be employed was furnished by Visich and Braun (1974, pp. 4-7):

1. the necessary equipment is not available because of the expense, or it is too complex or delicate to permit students to use it;
2. the sample size available in the real world is too small to permit generalization;
3. the experimental technique is difficult and must be developed over an extended period;
4. there are serious dangers to the student;
5. the time scale is too short or too long to permit the student to make observations;
6. the opportunity to experiment directly is not available;
7. it is sometimes desirable to measure variables which are difficult to access;
8. measurement and other noise may obscure the important phenomena; and
9. there are times when it is useful to underscore the significance of natural laws by comparing their results with other laws.

Flake (1974, p. 3) identified the four basic components of any simulation as

1. an abstraction of an environment;
2. a series of rules for how the model behaves or the models interact;
3. the freedom for the participant to interact with the simulation to develop strategies; and
4. "reality feedback."

According to Flake, the first two components are the actual simulation, while the other two are the factors providing motivational character by adding a gaming aspect which makes the activity come alive—that is, approach reality. Thus, by use of simulations in educational settings, students can:

1. investigate a wide range of significant experiments within a reasonable time frame,
2. visualize conceptual relationships,
3. change relationships and observe the results;
4. exercise and develop their own judgment and witness properly and without penalty the results of their decisions;
5. experiment without the usual frustrations of complex laboratory techniques, where the concept is the primary goal;
6. manipulate phenomena and laws to their own satisfaction;
7. control the learning environment instead of observe it;
8. focus on those aspects which are of prime concern; and
9. study more content in a course without limiting depth or increasing the time burden on the student (Rubin and Geller, 1977, pp. 91-92).

Crawford and Purcell (1974, pp. 43-44), in applying such goals as those listed above to environmental education, suggested that the educational goals of simulations relating to environmental concerns are to:

1. provide opportunity for participants to interact with a cross-section of society;
2. experience exposure to many academic disciplines;
3. realize that problems are complex and based on values;
4. experiment with modes of negotiation (be taught to compromise); and
5. become aware of actions and see the consequences.

Why Time-Sharing?

The magnitude of computer simulations such as APEX, CITY, and the River Basin Model assures their impracticability for most instructional situations; they require too much instructional time, too much computer time and capacity, too much staff support, and too much sophistication on the part of both instructor and participant to be of general use. To use them as designed, mainframe computer access must be readily available, and such is not the case for most instructional situations.

Rapid advancement in the use of computer simulations for instructional purposes was promoted by the development and institutionalization of computer time-sharing options in the late 1960s. Batch processing of data cards was readily adaptable to numbers of users sharing the same mainframe computer; a modification using telephone lines to input data followed logically. In the latter type of time-sharing, a number of "users" subscribe, or otherwise gain access, more or less on a demand basis, to time, space, and programming capabilities of a mainframe, or perhaps a mini-, computer. Access is frequently, and often most conveniently, accomplished via telephone hookup through a "dumb terminal" (one which has no computing capability of its own, but is designed to act as an intermediary between a "user" at one point and a computer at another). The computer itself can be anywhere, so long as a compatible hookup is available. This arrangement continues in common usage for a number of commercial or quasi-commercial applications such as access to large data bases of the ERIC variety, but it is no longer the most common purveyor of instructional simulations.

A number of instructional simulations developed from the models of Forrester (1971) and Meadows, *et al.* (1972) made use of telephone hookups to mainframe computers. *WORLICS* (Haller, 1972) provides an example of a multiple variable person-machine simulation in which the student participant attempts to achieve a global equilibrium while manipulating the variables of the Forrester model, because the basic model is in effect Malthusian, equilibrium is difficult to attain.

What Materials Became Available?

Among computer simulations useful in environmental education settings which involve, or may involve, time-sharing options is a set developed by the Huntington Computer Project at the State University of New York at Stony Brook, under sponsorship of the National Science Foundation. Materials associated with these simulations have been distributed commercially by Digital Equipment Corporation. The programs themselves were written in BASIC. Titles in the series are briefly described below.

POLUT (Braun, *et al.*, 1971a and 1971b) is a program providing a simulation of the interaction between water and waste which creates a context within which the user can control specific variables which affect the quality of a water resource. Output is in both tabular and graphic forms. Flowers (1980) described his experiences in using this program with high school biology students, while Chalmers (1981) used this simulation as his primary example in a discussion of the development of computer activity in environmental education in New Zealand.

BUFLO (Braun and Friedland, 1974), is a simulation which allows students to study the historical and biological reasons for the near extinction of the American bison. BUFLO simulates the natural life cycle of the bison and allows the student to manipulate harvesting policies to reach goals outlined in a student handbook.

MALAR (Friedland and Frishman, 1973) is a computer program which deals with malaria and its eradication, allowing the senior high school student to attempt to control, through manipulation of appropriate variables, a simulated malaria epidemic. Provided is a context within which to study the biological, economic, social, political, and ecological aspects of a classic world health problem.

PH (Friedland, 1973a), a computer program consisting of three different laboratory investigations dealing with the pH specificity of enzymes was designed to allow high school students to determine a possible explanation for pH specificity in an experimental, mathematical fashion.

POP (Braun and Friedland, 1973) was designed to allow a student with little mathematical background to explore various simple mathematical models of population growth. Student exercises revolve around the growth of a gypsy moth population. Three variations of population modeling are included. POP 1, simple exponential growth, POP 2, including an environmental limiting factor; and POP 3, which includes both an environmental limiting factor and other modifications.

RATS (Frishman, 1974) is a model simulating the dynamics of a rat population in either a city or an apartment house. The student controls the conditions of growth and sets the points at which the computer program prints reports. The rat population is controlled by variables including garbage levels selected for the site, and types and quantities of poison applied. At the conclusion of the simulation, the program prints details concerning the nature of the rat population, the dollar value of damage done by the rats, cost of poison, and amount of poison left uneaten.

TAG (Friedland, 1973b), a model for estimating animal population in a given area, asks the student to estimate the number of bass in a simulated farm pond, using the technique of tagging and recovery. The objective of the simulation is to teach principles for estimating animal populations when they cannot be counted directly or when counting would disturb or harm the animals.

USPOP (Friedland, 1973c) is a human population model in which variables affecting the population dynamics of the United States may be manipulated. Baseline data are drawn from the 1970 census. Variables which can be manipulated include fertility, age of mother at birth of child, sex ratio of offspring, and age-dependent mortality.

The University of Illinois PLATO computer system has been involved in computer-assisted instruction in many educational areas for a number of years. One PLATO program (Klaff and Handler, 1975), the Population Dynamic Group, involves computer-generated visual graphics which enable fast and intuitive understanding of the dynamics of population and of the concepts and data of population. Basically, the program is a population projection model designed to forecast the populations of more than 120 countries, based on either constant or changing 1970 demographic parameter assumptions. Basic data include 1970 total population, age composition categorized into 18 five-year intervals, age-specific fertility rates, and a cohort specific mortality rate schedule. Other programs in the series contribute additional parameters, including economic development, educational development, food demand and supply, energy demand, labor force analysis, migration and urbanization, population history, and birth control use.

Are Energy-Related CAI Programs Available?

A set of five energy-related computer-assisted instruction programs were developed as units of instruction by the Northwest Regional Educational Laboratory (NREL) in the middle 1970s under sponsorship of the National Institute of Education, as Computer Technology Program Environmental Education Units. Included were:

Consume (NREL, 1975d, 1975e), a unit exploring U.S. energy consumption in terms of growth in demand, problems associated with converting and distributing energy, new energy sources, and transportation and energy consumption;

Energy (NREL, 1975f, 1977a), simulating the pattern of energy consumption in the United States, the demand for energy is shown to grow exponentially in each sector—industrial, transportation, utilities, and so on; students are asked to balance supply of energy with demand by adjusting factors in each sector;

Attitudes (NREL, 1975b, 1975c), dealing with the attitude of people toward gasoline shortages and different steps that government might take to reduce gasoline consumption; students consider methods of reducing such consumption, explore the attitudes of people toward these methods, learn that people's attitudes differ, and form and express their own attitudes;

Earth (NREL, 1975a, 1977b), organized around a comuterized data base of information related to global energy use; the data are organized on a country-by-country basis for the 83 largest countries in the world; for each country, data are stored on 24 variables such as use and production of energy, per capital income, energy reserves, etc.; students are guided through a series of inquiries into the data base;

Future (NREL 1977c, 1978), exploring the thirteen main energy-related decisions proposed in President Ford's 1975 State of the Union Address by simulating the effects of any combination of the decisions on energy supply and consumption, on domestic production and reserves, and on pollution.

What Are Multi-User Computer Simulations?

A multi-user interactive computer simulation (MICS) can provide input from a number of participants at one time, summarizing interacts and sharing results simultaneously with all participants. According to Mills (1984, p. 152), "In addition to simultaneous group interaction, a MICS models situations where relevant environmental concepts and issues are considered objectively in the absence of excessive emotional bias common to local site-specific . . . issues. Emotional involvement is present, but not to the extent that it interferes with consideration of rational objectives."

Using an MICS format dealing with energy resources and an Energy-Environment Simulator provided by the U.S. Department of Energy, Dunlop (1979) studied the effect of simulation on inservice teacher energy-related attitudes. He found that elementary teachers' attitudes changed to a greater extent than did those of secondary teachers, leading to the suggestion that a lack of initial awareness of issues involved may have accounted for the greater shift. Fazio (1979) described a mini-course on energy and environment for non-science majors in a liberal arts setting wherein the same simulator was used to provide the student with a background on energy and environmental problems. Cartwright and Heikkinen (1981), also using the same device, found that it was more effective than a slide presentation with respect to the development of energy concepts and attitudes of college students at various levels of cognitive development, and that students at lower stages of cognitive development learned almost as much as did more cognitively mature students. Other reports describing the use of the Energy-Environment Simulator have been published by Sell and Van Koevering (1981a, 1981b) and by Zielinski and Bethel (1983).

Two reports of a similar device being used as a water resources management simulator have been published. Amend and Armold (1983) described its use in a program designed to improve public awareness/understanding of major factors in managing water resources, placing lay people and teachers in decision-making situations involving real variables and alternatives, then projecting for them the probable consequences of their water management strategies. Mills (1984) found the water resources management simulator to be an effective water information dissemination tool, particularly at the senior high school and adult levels, as well as an effective method of increasing concern for water issues. This simulator offers a visual model of hydrologic information and provides up to 30 participants at one time the opportunity to develop and evaluate water management strategies.

What Are the Impacts of Microcomputers?

It was not until computers became available on a classroom basis, rather than a time-share basis, that general interest in them as instructional devices developed (Naiman, 1982). As stated by Helgeson (1982, p. 1):

> With the development of integrated circuitry and the silicon chip, computers shrank in size and cost. The appearance of the microcomputer for personal and general use in 1977 brought about an immediate surge of interest among educators ... The microcomputers were portable and could be placed in the ... classroom where they were needed. They were reliable; if they malfunctioned, they did not wipe out everyone's work.

The microcomputer provides a clear example of what happens when a technology develops faster than does demand for it. Apparently overnight, the technology—the hardware—existed, it was immediately apparent that many more uses, and much greater potential demand, were possible than had at that point in time been identified. The rhetorical question is obvious. what uses, and markets, might be developed? An ensuing question is no less logical: is education an area, and potential market, for this new technology?

Luerhmann (1982, p. 14) noted the potential educational benefits of the computer as follows:

> The computer is unique among information technologies in that it permits intelligent interaction with the learner. All previous information technologies have been one-wav paths for distributing facts and ideas. This is true of printed books, audio recordings, and broadcast or recorded television. The computer alone permits the learner, at his own pace, to interact with his efforts—to construct a correct algorithmic representation of the problem—or with a teacher's programmed dialogue. The computer is also unusual in that an individual can learn to use it constructively as an aid to conceptualizing and solving problems.

As Ingoldsby pointed out several years ago (1978), the cost of micro-computers was relatively low and generally tended to remain constant or even to decline as computer power increased. This still true; because their cost has been low enough to make it possible at least to consider equipping classrooms with microcomputers, and distributors have actively promoted sales to educational institutions across the grade-level spectrum, prekindergarten through graduate studies, in part by aggressively promoting the development of software which, as it becomes available, assists in creating demand for their hardware. A survey reported by Ingersoll (1983) indicated that in 1981-82, microcomputers were located in one-third of the schools in the United States.

Have CAI Materials Proliferated?

The next section of this bulletin briefly reviews a number of computerized instructional materials which have been reported through the ERIC system during the past several years, with the range of selection limited to topics of interest to those involved in environmental education. These titles are in addition to those simulations described above. Most, though not all, were designed for microcomputer usage, it is probable that the others are generally adaptable to it. Also generally, the entries below are in chronological order.

An adaptive landscapes simulation (Hull, 1978) was designed to be used by post-secondary students to construct adaptive landscapes of two types as an illustration of the expected effects of selection. This program simulates effects of selection on populations and changes of gene frequency, both of which can be plotted on the same contour map.

A report of a CAI approach to population dynamics (Boyle and Anderson, 1978) contains two computer packages which augment laboratory experiments in which the effects of random variables on population processes may be explored.

A set of simulation models for use in teaching population dynamics, designed specifically for use with a programmable pocket calculator, can be used to demonstrate growth of populations with discrete or overlapping generations and also to explore effects of density-dependent and density-independent mortality (Kidd, 1979).

The development of a mathematical model to simulate small animal populations was reported by Grier (1980). The paper discusses assumptions of the model and options in the program.

Wu (1980) developed several innovative and interesting energy awareness computer simulations to demonstrate how rapidly world energy reserves are depleted, how quickly and enormously the demand for energy grows, and the importance of energy conservation and conversion.

An International Futures (IFs) computer-assisted simulation game for use with undergraduate students consists of a global model representing the world in ten regional groupings, and deals with the issues of the rapid acceleration of global population growth, the uncertainty of food sufficiency, the degradation of environmental quality, shortages of resource (especially energy) availability, and the persistent gap between the global rich and poor (Hughes, 1981a, 1981b). The model, which has over 2000 variables, includes four major submodels: population, economics, agriculture, and energy. Each submodel separately represents each region.

Hayes and Allard (1981) reported on the effectiveness of an interactive computer-based instruction designed to give college students experience with exploratory drilling, as compared to a previously used field-oriented simulated exploration program. Their report discusses the development, operation, and implementation of the computer program.

Mayer, *et al.* (1981) developed a computer program to accompany a marine education program dealing with PCBs in fish; the program allows the student to input data on PCB content in fish provided in the activity, then generates graphs of that data, thereby assisting the student in its interpretation.

After outlining the difficulties of teaching climatology within an undergraduate geography curriculum, Unwin (1981) described and evaluated the use of a computer-assisted simulation to model surface energy balance and the effects of land use changes on local climate.

Gelovan (1981) proposed a problem-oriented, man-machine modeling process which combines algorithms and software to assist decision-makers and planners in dealing with complex socioeconomic issues. His paper includes the specific parts in each of the system's three basic elements—a library, special units, and system-control units.

A computer simulation, **Energy Search,** in which elementary school students manage their own factories has been described by Whittredge (1982). Provided are an example of typical classroom interaction and commentary on the nature of good computer simulations, described as those that teach skills and create an environment encouraging students to work together toward a common goal.

Considerations relative to microcomputer use with special populations of students, in this case hearing-impaired college students, are presented by Wilson (1982) in his discussion of a high-verbal-content "Energy and the Environment" couse. The three models presented illustrate the complexity of problem-solving and moral issues.

A rationale for and description of an acid rain game designed for two players, a problem-solving model for elementary students, has been developed by Rakow and Glenn (1982). The game is available both in computer-supported and non-computer formats.

A computer simulation game of the interpretive planning process, **Interp** (Macko, 1982) was developed to demonstrate the power and uses of computers to students of environmental interpretation, show the use of computers for modeling in the realm of environmental interpretation, and show the use of computers as learning tools for students of environmental interpretation. The object of the game is to draw up the best possible interpretive plan while working within the constraints imposed by a budget, deadline, and three components of interpretation—site, organization, and visitor.

As part of a paper describing computer programming for elementary and secondary school students, Canipe (1982b) provided complete listings of two programs, **Light Bulb** and **Blastoff,** written in Applesoft Basic.

A computer game designed to teach energy conservation concepts to upper elementary and junior high school students is **Groucho** (Canipe, 1982a). The game utilizes low-resolution graphics to reward students for correct answers to questions presented. The opportunity exists for teachers to include their own questions within the program and to use the graphics as positive reinforcement for correct responses.

Software developed for a course in which undergraduate students learn to program microcomputers while learning about their applications and ramifications includes "yellow light" (traffic flow), "domestic electrical energy use/cost," "water pollution," and "supermarket automation." (Liao, 1983).

A computer-assisted environmental education game **Terra,** designed to encourage lower-ability high school students to think at their own level about the future of their world, contains four programs—Terra Firma, Terradactyl, Inflation, Doubles (Watson, 1983). It is based on the Meadows, et al. **Limits to Growth** model (1972).

A computer program which is based on field observations of littoral zonation modified by a small stream has been described by Kent (1983). The program employs user-defined color graphic characters to display simulated ecological maps representing the patterning of organisms in response to local values of niche limiting factors.

An interdisciplinary college-level program which uses computer simulation exercises to teach about foreign policy and global issues provides opportunity for political science and foreign language students to role-play national decision-makers (Wilkenfeld, 1983). In this simulation, students debate demographic, economic, energy, and agricultural issues.

Geyer (1983) suggested that computer programming can bring about an understanding of several biological concepts which, because of their arithmetic implications, are often considered to be difficult. Population growth is used to illustrate his proposal, in which computing and the study of the topic at hand are integrated.

A course outline, including computerized simulation exercises designed as in-class activities related to science and society interactions, has been provided by Maier and Venzani (1984). Simulations focus on the IQ debate, sociobiology, nuclear weapons and nuclear strategy, nuclear power and radiation, computer explosion, and cosmology. Research reported indicates that learning improves when students take active, rather than passive, roles.

A middle school global studies course focusing on the developing world uses computers to show students how data can be used to understand phenomena (Traberman, 1984). Students secure data for one or two countries and, using the programming language APL, create tables, make maps, visuals, and graphs, and manipulate computer-generated models.

An interactive computer program modelling the colony dynamics of a social insect, the honeybee, has been described by McLellan (1983). Included is a program listing for PET microcomputers, in BASIC.

A Civil Servant Module, a new component of a Global Systems Simulation, is presented in a paper by Valadez (1983). The simulation is described as a comprehensive person-computer model for investigating international affairs, and deals with its telecommunication capability, logistics, functions, spatial flexibility, and advantages, as well as implications for applying the simulation as a research and educational tool.

Software packages on energy topics under development by the National Science Teachers Association's Project for an Energy-Enriched Curriculum (PEEC) have been described by Hall (1984). Although all are intended primarily for grades 7 to 12, some are also appropriate for higher education. Program topics include power plant engineer, energy conversions, personal energy inventory, temperature grapher, home energy savings, and electric bill.

A computer-based Wilderness Simulation Model (Manning and Potter, 1984) reduces the complexity of the outdoor system under study, allows students to act as managers (devising and testing their own management strategies), and increases student exposure to characteristics of actual park and wilderness areas. Two scenarios of recreational use patterns are analyzed.

An interactive optimization computer game for training resource managers (Rago, 1984) involves the user in playing the role of an environmental consultant to an electric utility company. Key components of a typical resource management conflict and techniques for determining optimal solutions through linear programming are discussed.

What Does Research Say?

To date, there has not been a great deal of "formal" research directed toward the effectiveness of computer utilization as an instructional technique. This is, of course, often the case when something new comes along—practitioners use it, and (as it becomes clearer that the "something new" is not likely to be a fly-by-night fad) researchers eventually investigate it.

Over the years, several studies have examined students' attitudes toward CAI. In 1970, Mathis, *et al.*, found that college students who experience CAI demonstrated a positive attitude toward this instructional technique. Similar results were noted in a 1967 study reported by Schwartz and Long. A study of King (1975) concluded that computer-based instruction is not a threat to humanization, and that it can provide opportunities for increasing effectiveness and personalization of the instructor-student relationship. A 1984 study by Fortner and Mayer detected no difference in attitudes toward the use of computers versus workbooks, but did find that students using computers exhibited a more stable attitude toward them over time. This suggests that such use provides students with a realistic attitude toward the value of computers in learning.

Cox (1980) determined that.

1. junior high school students can improve in problem-solving skills in a short time on a microcomputer,
2. a training session in organizing data into a matrix was successful in introducing a usable new strategy,
3. individuals worked better in teams than alone;
4. subjects were just as motivated when sessions were more infrequent;
5. influence of group interaction enabled subjects of all abilities to participate successfully in problem solutions;
6. all subjects adapted easily and quickly to the use of a microcomputer;
7. subject interest remained high regardless of achievement or variances of individual characteristics; and
8. microcomputers can be considered a viable, motivating aid for the development of some problem-solving skills of early adolescents.

Cox and Berger (1981) expanded on the motivational aspects noted above in a paper published in *Science and Children.*

Research examining the effectiveness of CAI in increasing levels of achievement as compared to other forms of instruction generally produces positive results. For example, Schar (1983) reported a statistically higher factual recall for post-secondary students exposed to computer simulations compared to students not so exposed. However, no significant differences in conceptual understanding of interrelationships between and among natural resources and populations, industrial growth, food production, and/or pollution were noted.

Because studies evaluating the effectiveness of CAI in the classroom are conducted in a variety of settings with a large number of confounding variables, their results are difficult to generalize. Some positive relationships between computer use and student attitudes were noted in a meta-analysis by Kulik, *et al.* (1983); the same report suggests that computers appear to be at least as effective as more traditional forms of instruction in affecting student achievement.

A number of cautions are appropriate as the educational community, including environmental educators, becomes increasingly involved in computerized education. Crovello (1982) points out that computer software should be evaluated by teachers, students, or administrators before and after (ongoing) purchase, and that reliable evaluations are performed only in the educational context in which students will be using the computer. Cohen (1980) has described the procedures for writing and developing educational simulations on computers, and briefly discusses the future for the educational simulation developer in computer simulation.

It is clear that opportunities for additional research and evaluation in computer-related areas of instruction abound, and will be seized. Practitioners face the necessity of deciding, on a much more personal, local level what their own uses of computerized instruction will be. Over a period of several years, it should be possible for the two groups to combine their interests and needs.

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