Evolution of Educational Software

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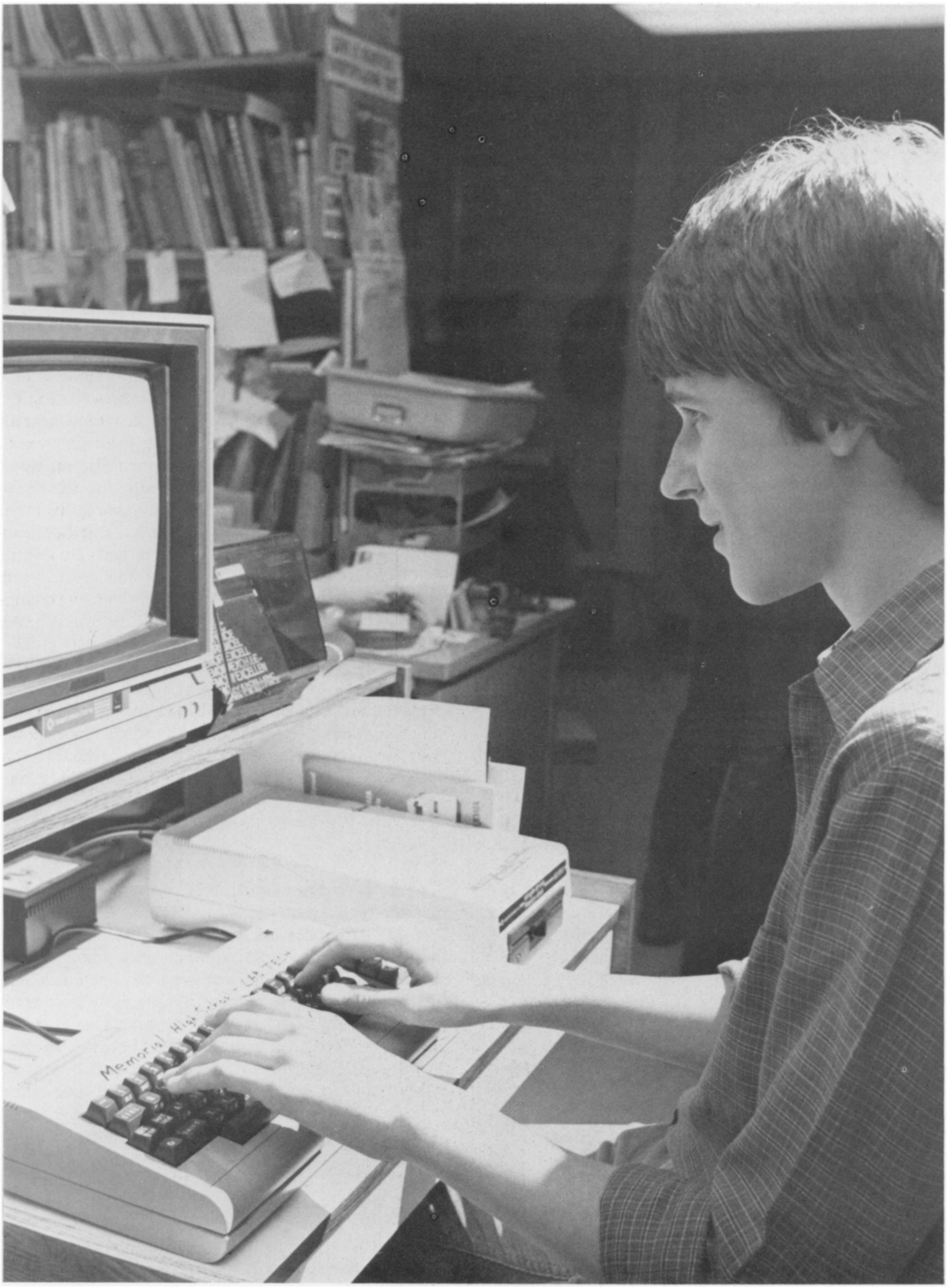
Educational software has existed almost as long as computers have been available in academic settings (Crovello 1974, 1980, 1982). The amount, diversity, and quality of such software has undergone great changes, and never as rapidly as today. This article will document the history of changes in educational software and predict future developments.

General Considerations

Just as organic evolution occurs in the context of the environmental system of the real world, so software evolution occurs in the real world of an educational computing system. It has three essential parts: hardware, software, and people. To neglect the simultaneous consideration of any two essential components while considering the third will prevent a total understanding of software evolution. Continuing the analogy, just as the environment in which organic evolution constantly changes, so too must we be aware of important changes occurring in hardware and in people with respect to educomputing. For example, while many educators use Apple IIs in the classroom today, they replaced earlier microcomputers; and they in turn are not the state of the art today. Major hardware characteristics important in educomputing that have undergone extensive change include increased abilities in storage, graphics, access ability, and decreased price.

With respect to computing, people have also changed. More educators have become more comfortable with computers and are less hesitant to consider their use. Others have become even more familiar with what computers can and cannot do, so that they are less ready to accept them as an educational panacea. Students at all grade levels are now able to do more with computers than ever before. The simultaneous evolution of hardware and of people's understanding of computers has greatly increased the number of bioeducators who have a positive mental attitude toward computing and now access to realistic educomputing power. The appearance of relatively low-cost, powerful microcomputers has changed the availability of computers from just selected college educators to their widespread availability at all grade levels.

The greatest impetus to expand educomputing today is due to the huge demand at the high school and grade school levels. This is partly because educators at these levels are full-time educators instead of having to divide their time between education and research. Many are highly motivated and will pursue any innovation that promises to enhance their teaching effectiveness. In addition, while quality software has been in short supply, perhaps more has been available at the high school level than at the college level because the programs need not cover topics in as


Memorial High School

much detail, and thus can be created more quickly. On the other hand, secondary school educators are more apt to demand that a program cover a broader range of topics. This could tend to decrease the rate of production of quality software.

As a result of all of the above forces acting on the education system and on the educational computing system in particular, the number of software suppliers is greatly increasing every year. The result is healthy competition which in turn is producing innovative, valuable software.

Since software is limited by hardware capabilities, let us trace the development of computer hardware. The dates given will be approximate. They represent not the year in which the hardware innovation occurred, but rather the year in which such advances became generally available to educators. In 1960 maxicomputers were available to some bioeducators in the nation's colleges. In 1965 minicomputers began to appear in biology laboratories. While most of their use was for research, some professors also introduced them in their courses. Nevertheless, their price (usually above $20,000) kept them out of the hands of the majority of educators. In 1970 remote terminals linked by normal telephones to maxicomputers helped to forge a new revolution in educomputing. Now a relatively inexpensive (under $1,000) purchase of a computer terminal and modem was all that was needed to provide computing power in the biology teachng lab. Large federally and commercially funded projects came into existence. Perhaps the most famous is the PLATO system, a joint venture of the University of Illinois and Control Data Corporation, aided by millions of dollars from the United States Government. The development of educomputing from 1960 through about 1978 is a story of logarithmic or sigmoid growth, no matter what hardware and subsequently software characteristics we might consider.

While the earliest microcomputers became available commercially around 1977, 1980 is more accurately the year when large numbers of educators began to use them. From 1980 to the present, microcomputers changed significantly the evolution of hardware and thus of software available to educators. In certain characteristics (amount of available memory, speed of computation, etc.,) maxicomputers continued to grow in abilities. But microcomputers caused two qualitative changes, one producing increased capabilities and the other a set of decreased capabilities (at least for the next few years). Among the increased capabilities immediately available were characteristics related to color, sound, and response time. Characteristics that suffered by switching to microcomputers (compare catastrophe theory in evolution!) included speed of calculation, speed of access of data in mass storage such as on disks, and level of graphics resolution. Today 16 and even 32 bit microprocessor-based microcomputers are becoming available, as is large-scale mass storage on hard disks (measured in megabytes, millions of characters of information). The result is that we educators soon will have much of the capacity of maxicomputers on our learning lab tables!

The evolution of microcomputer software can be observed at two levels. First is the evolution of a particular program (such as one of the early Huntington II simulations). It had a birth; the program changed, being modified by the authors as well as by users; now perhaps it is being used less and less, being outcompeted by more recent programs that accomplish the same objectives better. Alternatively, it might survive longer by finding a new niche at a different grade level or with a different group of students. At the second level consider the evolution of the entire set of bioeducation programs available at a given time. For example, currently we see an increase with respect to the number of programs available for a particular topic (such as predator-prey relationships or Mendelian genetics). We also see an increase in the number of topics for which programs are available. Finally, we see that the scope (amount and depth of coverage) of many programs has increased. This is the confusing but dynamic reality of the state of the art of educational software!

One final relevant topic can only be mentioned here. That is, along with the evolution of software we should realize that there exists an evolution of actual use of software. For example, a recent survey indicated that with increased number of years of using microcomputers, students (and more importantly their teachers) decreased the relative percentage of time devoted to drill and practice and increased the percentage devoted to programming and simulation.

Stages in the Evolution of Educational Software

While software evolution is perhaps more like a continuum, it is instructive to recognize several stages. *Primitive* programs are quick and simple programs; they are relatively quick to write and perform relatively simple tasks (they need *not* always be quick and *dirty* as some have suggested). Many early maxicomputer and early microcomputer programs were of this type. They rarely were intended to be used by students in the absence of a professor or teaching assistant. Nor were they intended for use at other schools. Gradually the programs became *civilized.* These are in part characterized by being *standalone software,* allowing the user to use the program profitably without help from an educator before, during, or after the computer session. In other words, the program is relatively self-contained and considerable efforts have been made to prevent students from accidentally terminating the program or becoming frustrated or bored. In addition, extensive use is made of a "Help" option. The result is that questions about the subject matter often can be answered by the computer program instead of by an educator. Many commercially available programs today are civilized to some degree.

Intelligent Computer Assisted Instruction (I-CAI) is the next stage in the evolution of educational software. Unfortunately, at present no examples exist in biology. The goal of I-CAI is to create intelligent computer based tutors that simulate the behavior a human tutor might give in different ways to different students in a class. To date I-CAI has concentrated more or less on drill and practice and tutorial educational strategies. We can expect development of strategies involving simulation, etc. as artificial intelligence expands to cover all computer assisted education and thus becomes Intelligent Computer Assisted Education (I-CAE).

Multi-faceted educational software is mainly still in the future. It will incorporate the good qualities of the previous types of software just described. But its major characteristic will be to focus on a particular subject, from *many* aspects. For example, if someone is interested in maple trees, the program maple may allow the user to explore many topics, including the following: maple taxonomy; maple phylogeny; chemicals found in maples; worldwide distribution of maples; economic uses of maples; maple insect and fungus problems; simulation of maple tree growth, etc.

Let us summarize the state of the art of educational computing in terms of the above stages. Currently and for the next decade different educators and companies no doubt will be writing or offering programs of all of the above types, either because the authors are new to the field or because each type of program can serve a particular need. However, probably relatively few bioeducators will do much programming themselves. They will find that students will be able to create primitive, quick, and simple programs at least as quickly as they can. But more importantly, students will also learn much more about the biological phenomena by quickly programming a computer to analyze them. So let the students program! For the more sophisticated programs, bioeducators will find that it requires too much of their time, time which will be added to all of their ongoing tasks. And even then their programs will not be equal in quality to many from commercial sources.

Some General Questions

Since microcomputers have been used in bioeducation for several years, we can consider several important general questions. Many educators now have the necessary classroom user background to think intelligently about what the role of educational computing can and should be. Such considerations include whether increased computer use will humanize or dehumanize our students; whether increased computer use can help forge positive attitudes toward lifelong learning in an increasingly information-based society; and whether increased computer use may make education more dull or more exciting. Ultimately the answers to these and similar questions depend on how we as individual educators use computers in our classroom.

Changes in General Software Characteristics

While great strides have occurred in the evolution of individual programs (from primitive, to civilized, etc.), relatively little change has occurred in programming languages such as BASIC, at least those that are used widely in educomputing. On the other hand, currently we are witnessing accelerated growth in the number and capability of utility, or applications, programs. These include programs for word processing, statistics, graphics, drill and practice tutorials, computer managed instruction, and interfacing laboratory equipment. While languages such as BASIC have serious shortcomings (in both their interpreter and compiler modes), they are relatively easy to learn. More powerful languages already exist. But for educational uses I suspect that the growing educational market will make it cost effective to devote significant resources to the creation of even more powerful applications programs than those that exist today. So we can expect applications program packages that will allow users (educators or students) to instruct the computer more quickly and in ways more like a natural language such as English. For example, in a simulation package if users want to create a scatter diagram of a sample of traits A and B, they need just type, "GRAPH A, B."

As an example, Micro-DYNAMO is a systems modeling "language" that permits simulation of biological, social, economic, and other systems. Users create their model in the DYNAMO language and specify in simple statements what variables are to be printed and plotted. Micro-DYNAMO is now available for the Apple II and IIe systems. It is actually written in Pascal, but naturally users need to know nothing about Pascal to use Micro-DYNAMO. It is available from Addison-Wesley Publishing Company, Reading, MA 01867; $245.

Changes in Specific Software Characteristics

Specific improved characteristics include the following: increased user helpfulness and a more positive psychological personality conveyed by computer programs; increased protection of input and output files; increased use of the Help option; increased use of program prompts for users who are uncertain of the correct answer or what to do next; increased use of natural language responses such as allowing users to type in prose answers rather than just indicate by a letter which of several choices is correct; increased use of high resolution graphics, animation, and color; increased use of the capabilities of the microcomputer to move around the screen instead of just linearly from top to bottom as was required in many maxicomputer systems; use of different type fonts on video display terminals and of spacing to include blank areas when this seems appropriate; the availability of several levels of difficulty or complexity of a topic; increased branching capabilities, increased user-control throughout the program; and the ability to save results of one session to work on during a subsequent session.

While present civilized programs have certain characteristics such as user protection and user friendliness, already we see a continued evolution within civilized programs such that it is correct to say that some are more highly advanced or evolved than others.

Let us consider user control and user orientation in detail. Maximum *user control* means that the user is in maximum control of the computer session. Each user of the same program decides what to do next, as opposed to the computer making such decisions. *User orientation* defines the role of the user with respect to other users and the computer. Several possibilities exist. The user may be competing with the computer or be competing with other users who compete with the computer. Or both the computer and other users may be cooperating with each other to achieve a common goal. Cooperation instead of competition appears to have pedagogic advantages. As an analogy, few educators can increase student learning by squaring them off against each other (all of the educational world is not a spelling bee). Students like to work with their peers and also to use the computer as a friendly source of information and analysis rather than an adversary. Such cooperation does not mean constant agreement on all matters. A good example of educationally stimulating computer programs is the "Search Series" in energy, geography, geology, etc. (Webster Division, McGraw Hill Book Company, 1221 Avenue of the Americas, New York, NY 10020). While oriented for students in grades 5-9, the idea and philosophy of these programs is important. It presents the students as a group with a common problem and demands that they find the best solution through discovery learning.

Another characteristic of educomputing software evolution is the particular uses to which they have been put. Early uses concentrated on drill and practice or tutorials with animation. While these and all uses are still important in certain contexts, simulation, statistical, and graphic analyses are now being used effectively. Data retrieval (and not just literature retrieval), is used when such data bases are available. Test generation, and course management in general, also is being used more. Most recently the general purpose microcomputer is appearing in teaching laboratories. They have not appeared sooner and in more abundance because their use in such situations requires a certain amount of special programming and hardware that usually is not available from microcomputer vendors. Several companies now offer the necessary hardware and software to interface laboratory teaching equipment to computers. HRM Software (Pleasantville, NY 10570) offers "Experiments In Human Physiology" and "Experiments In Science," for $249 each. The first allows ten experiments to be performed, including those related to skin temperature and heart rate. Cambridge Development Laboratory (100 Fifth Avenue, Waltham, MA 02154) offers similar interfacing hardware and software. A journal dedicated to this area is Computer Applications in the Laboratory (60 Ridgeway Plaza, Suite 3, Stamford, CT 06905; 4 issues per year at $35). Some free journals (supported by advertising) frequently have articles or special issues devoted to laboratory automation (e.g., American Laboratory, P.O. Box 485, Arlington, MA 02174). Graef (1983) gives a clear introduction to laboratory interfacing.

Future Evolution of Educational Software

Predicting future software evolution can be as challenging as predicting organic evolution. Some aspects seem more certain, however. Many of the trends and characteristics of educational software described throughout this paper will become reality. For example, more programs on more topics will be available. They will be more user helpful, more realistic, and able to educate a heterogeneous group of learners better. Programs with artificial intelligence will respond in specific terms when a student asks, Why! In many cases computer use will be an integrated part of a course (e.g., Crovello and Smith 1977), instead of dealing with only isolated topics. More programs will actually be "integrated" program packages! They will allow users to easily switch from one task to another, e.g., carrying out a data search, then creating graphic summaries of them. As programs allow students greater control, we can see that the role of the *computer* will change from its being the tutor to being a tutee (Taylor 1980). We can expect programs that require increased amounts of role playing by students, and that require several students to interact with the computer simultaneously. This last will be made easier as microcomputer networking increases in popularity.

We also can expect continued breakthroughs in hardware, or even just new uses in education. For example, videodisc technology has been available for several years, but the market for them in education has been developing slowly. How many schools or departments own a videodisc player, and of those, how many have the hardware to interface it to microcomputers? And then, assuming the videodisc hardware is available, where is the software to interact with the videodisc? Then we still require the videodisc to have relevant subject matter in the discipline we are teaching. Otherwise, interfacing hardware and software have little educational value. These thoughts produce a feeling of *deja vu*. They recall the continuing problems confronting educators when we try to choose computer hardware. We have to consider the entire educational computing system, including available software and type of people (Crovello 1983).

Yet, two recent videodisc projects in biology indicate that interfacing software and biology videodiscs will soon have an impact on educomputing. Professor W. Leonard (Department of Curriculum and Instruction, Louisiana State University, Baton Rouge, LA 70803) has interfaced a videodisc with the TRS 80, Model 3. It includes material on biomes and respiration. Currently it is being field tested at several sites. Cost of the required equipment today is about $5,500, but within two years he estimates that it will drop to about $1,500. A videodisc with 6,000 2 by 2 slide images and some action scenarios was just introduced by Videodiscovery (P.O. Box 85878, Seattle, WA 98145). Its purchase price of $495 includes a cross reference "image" directory. Hardware interfacing between an Apple and videodisc player costs several hundred dollars.

Large commercial publishers have just entered seriously into educomputing. Their contribution will be significant because for several reasons they are approaching courseware development very thoroughly. An interesting interview with educomputing administrators at several publishers appeared recently in the AEDS Monitor (volume 27, pps. 8-13).

We also can expect the development of an entirely new area in educational and cognitive psychology centering on computers in education. A particularly important aspect will be the user-computer interface. Recent research papers in this area include those with the following titles: "An experimental investigation using the computer as a tool for stimulating reasoning skills"; "The effect of all capital versus regular mixed print, as presented on a computer screen, on reading rate and accuracy"; and "Linking knowledge, realism and diagnostic reasoning by computer-assisted confidence testing." Even entire books on a specific topic are beginning to appear, such as screen design strategies for computer assisted education (Heines 1983).

The future developments mentioned to this point are relatively certain. The next topics are important in future software evolution, but are less predictable. We can begin with a series of questions. Can computers increase levels of discovery learning, of focus on process instead of content, of problem solving, and of critical thinking? What type of software will be best to achieve these goals? Will all grade levels and types of students benefit equally from computer use? Even if yes, will different types of students in the same class benefit most from the same type of programs? We still know too little about how computers can be used to optimize individualized instruction.

We also must remember that the future evolution of software will occur in a more computer-oriented society. In his popular book, *The Third Wave*, Alvin Toffler states that over the next 10 to 20 years, 20% of the work force will work at home, and education will shift from the school room to the home, mostly due to computers. A serious concern is whether such a shift will result in integrated learning using positive interactions between the home and school, or whether home and school will become isolated "islands of learning" as Fred D'Ignazio describes them (*Compute!*, October 1983:138). Just who will dictate what types of software should be used in such situations? Will we educators give up our rights of decision to administrators or to what is available in the market place? As a specific example, will we agree to an administrator's or a school board's request to replace *all* biology laboratory sessions with computer simulations, or will we actively work for the soundest pedagogic solutions?

Educational software will continue to evolve rapidly. We can expect more and better programs as detailed in this paper. But their effective use in each of our particular courses will require serious thought and evaluation. In other words we must continue to be what we are, dedicated professional educators!

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