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ABSTRACT

Asserting that advances in hardware technology have outstripped educators' anticipations and that software is the key to the successful use of computer hardware, this paper addresses developments in both hardware and software and discusses possible directions for computer use in education. The first section covers the physical attributes of computer hardware and describes changes in memory, operating systems, storage capacity, and input output devices between 1970 and 1985. The decrease in cost of computing power is also described. The paper then examines software developments and asserts that although improvement in instructional software is slow, it is real and can be expected to continue. Characteristics of software are divided into three categories--subject matter content, instructional process or pedagogy, and technical characteristics--and advances in each of the areas are examined. A nine-item bibliography is included. (THC)

Alaska Department of Education

OFFICE OF INSTRUCTIONAL SERVICES

The Future of Educational Computers

Concept Paper

THE FUTURE OF EDUCATIONAL COMPUTING

Prepared for the Alaska Department of Education

by the
Computer Technology Program

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INTRODUCTION

To think of the future of instruction and the role of computers in it is intriguing. To predict it successfully has been frustrating for those who have tried. Most of the time, advances in hardware technology have outstripped educators' guesses. On the other hand, hypotheses about great change in the structure of the schooling process because of computers have not been borne out. A typical elementary or secondary school does not operate in a greatly different manner than it did 15 years ago. On the other hand, schools have acquired many more computers than many of us in the field of computer education thought possible five years ago. Software is the key to successful use of computer hardware in any field. The development of it for instruction has made great strides, but the more teachers see, the more possibilities are evident, and the higher are their expectations and desires. In this concept paper, we address both hardware and software, and discuss some of the possible directions of development.

HARDWARE

In looking to the future, it is instructive to see where we've been, and how far things have moved in a time period. In 1970, the type of computer frequently used in schools for drill and practice and simulation in instructional settings was a minicomputer of 8K main memory (core), containing a small version of BASIC, and measuring about 20 inches wide, 12 inches high and 24 inches long. It could fit on a desk or table top. Its primary input and output device was a printing terminal, having a keyboard and printer in the same case separate from the computer. These were usually the size of a typewriter, and being primarily mechanical rather than electronic, were very noisy. CRT terminals with black and white screens were sometimes used, in which case a separate printer was needed. Mass storage was magnetic tape or disk, with the disk capacity in the range of 5 to 10 megabytes, with either device in a large cabinet. The operating system and language had to be loaded from tape.

In the period 1970-72, the minicomputers expanded in power and size, and became timesharing computers supporting up to 32 terminals simultaneously. Up to 32 students could use the same computer at the same time, and each could be using a different program. Typically, the student used a terminal much as a microcomputer is used today, with access to main memory of 16K to 64K, and a portion of a 20 to 40 megabyte disk. An individual student might be allocated 128K of the disk. The operating system and language were in main memory.

In the period 1977-78, microcomputers began to be used in schools. Early versions had about 8K main memory (RAM), contained a version of BASIC, and measured 15 inches wide, 15 inches high and 18 inches long. A complete unit including keyboard, processor and CRT, could easily fit on a desk top. Magnetic tape or disk were the mass storage devices. The CRT was black and white, or color.

In 1984-85, the typical microcomputer purchased for instructional use was about the same physical size, but had 64K RAM, a disk drive (or two) with a floppy disk of 140K capacity and a color CRT. People were experimenting with the idea of tying 16 or 32 of them together to share a large disk of 20 to 40 megabytes capacity. Each student could be using a program different than the others. The operating system and language were in Read Only Memory (ROM).

Comparing the physical attributes of the hardware, we have seen great decreases in size and weight of the processor and disk drive containers. Advances in micro electronics have resulted not only in smaller components, but also in greater power in terms of processor speed and the amount of information which can be stored in a given space. Reductions in heat production have eliminated the need for fans. There are practical human limits to the size reduction of keyboards and visual displays, which tend to have remained the same size. The net effect is a much lighter and somewhat more compact student station, with mass storage at the student's fingertips.

The decrease in cost of computing power is probably the most dramatic change which has taken place. The cost of the 8K mini with printing terminal in 1970 was about $8000. The cost of the 64K micro with 140K disk and color monitor in 1984-85 was about $1000. Thus, the standard student station is more than 8 times as powerful at one-eighth the dollar cost, or perhaps one-sixteenth the cost if inflation is considered. These cost reductions have made it possible to provide computer access to a vastly increased number of students.

In actual computing capabilities available to the student however, note that we have come through two quite similar cycles. In the period 1970-76, an individual student station changed from 8K RAM and tape storage to 32K RAM with 128K disk space, using minicomputers. In the period 1977-85, the station changed from 8K RAM and tape storage to 64K RAM and 140K disk storage, using microcomputers. At the end of both cycles, the idea of stations sharing a central mass storage device containing a library of software and databases was commanding a lot of attention.

As we move into the 1985-86 year, the newly purchased microcomputer for instruction will have 128K RAM, disk drive and high resolution color monitor for about $1000. In one case, the Atari 520ST, it appears that that amount of money will buy 520K RAM, 360K disk drive and a color monitor.

It should be noted that we are describing what is being acquired by schools or marketed to them, not the ultimate technological state-of-the-art for that year. There is a lag time, and one can always pay more money to acquire higher power and capacity.

In the last 3 years, the common instructional micro has doubled each year in RAM capacity, from 32K to 64K to 128K, while prices have dropped about one-third overall, from $1500 to $1000. If those trends continue, we could expect the common student station in 1989 to have 1 megabyte of RAM, and cost $700.

In the last two years, a different configuration of microcomputer has become available, although not widely used in schools as yet. It is the so-called lap computer. The Radio Shack Model 100 and 200 are examples of the most common type. They are about 8.5 inches by 11 inches by 2.5 inches, with keyboard and built-in liquid crystal flat display. Current models are 32K to

64K RAM, and disk or tape cassette storage can be attached. They are portable and operate on rechargeable batteries. The operating system, BASIC, and standard software application packages are all built-in. The software includes a word processor, file manager, telecommunications, and in some cases a spreadsheet package. Outlets are provided for printers, tape, disk, and telephone. The cost of a basic unit of 32K RAM for an educational institution is about $500. The pattern of development for this packaging of computer power was similar to the two cycles previously mentioned, although shorter. The device started with 8K RAM and expanded to 32K in a period of 2 years, but the price dropped by half in that time.

This is an interesting development in packaging from an education environment standpoint, both for the near term and long term future. If the same trends are applied to this machine as the others, we should expect such a computer in 1989 to have 256K or 512K RAM, at a price of $250. If even modest improvements in the display are made, it would have a flip-up screen of 80 columns and 24 rows. The package would be about the same size, from a student's standpoint, as a 3-inch 3-ring binder, and hold over 70 pages of text (at the 256K level).

The packaging of major software in ROM is also interesting. With ROM capabilities increasing in parallel with RAM, the number of built-in applications, and their capabilities, should both increase. It appears, then, that the 1989 lap computer could be as capable as the 1986 desk-top computer, without the need for program disks for standard functions, as easily carried as a notebook, with a capacity of a dozen or more essays, book reviews, outlines, etc.

Aside from processor capabilities, auxiliary storage technology is also developing rapidly. Optical disk read-only-memory is of particular interest because of its imminent availabiliity as a consumer item, and thus a school item. The CD-ROM version (Compact Disk - Read Only Memory) will have a capacity of about 550 megabytes, roughly equivalent to 3900 floppy disks of the type common to Apple II micros, or about 200,000 pages of text. An entire encyclopedia could be easily contained on one disk. Such a massive amount of information would be randomly accessed in seconds by a microcomputer. In fact, the Atari 520ST mentioned earlier will have a CD-ROM player available at a cost of $500. We can envision, then, a CD-ROM player and microcomputer in each classroom, with collections of encyclopedias, literature, art and other information databases on disks on a handy shelf. A student would need only a few minutes to retrieve relevant information on a topic of study. Since the search software is easily defined using standard algorithms, a small micro of the lap style mentioned earlier could be a dedicated station with the CD-ROM device, having the search software built-in.

The CD-ROM technology has another possible impact. Because it is inexpensive, updated databases could be sent to users on a regular subscription basis, say quarterly. This means that a school could have many databases, quite current, in the building for access, so the need to use database utilities such as Dialog or BRS could drop drastically. This is important because the cost of telecommunications is rising, so that CD-ROM becomes not only a more convenient but less costly option than on-line database access.

To sum up the hardware trends, we should expect exponential increases in storage capacities of micros with decreasing costs, and improvements in color and flat screen display technology. Schools should be able to buy more capabilities for less money. While there are practical limits to the reduced size of keyboards and video screens, other components will reduce in size. Very dense optical storage devices will be available at low cost. Computer packages such as the lap or notebook microcomputer will be available, making it convenient to have a computer in many situations other than the standard environments of the last few years.

SOFTWARE

Compared to the progress in hardware developments, changes and progress in software seem less dramatic and much slower. The progress in instructional software development exhibits the same pattern as computer software in general: it lags behind hardware development. The design and production of software is a creative activity, and labor intensive. The two cycles of instructional computing mentioned in the hardware section, 1970-77 and 1977-85, show repetition of effort for software as well. Much software developed in the first cycle was converted for use on microcomputers in the second. At least, in the software case, new effort built upon the old, whereas with hardware not much of what we learned was passed on to the second cycle.

One of the common threads of the two cycles is that they both eventually began to focus on the idea of networks to share resources. The motivation in both cases was to achieve cost savings. In the case of timesharing systems in the first cycle, the objective was to share the computer and storage hardware because of their high unit cost. That the software library was also shared was of less importance, although the maintenance of a single library copy rather than multiple copies of a program did help. As we moved into the second cycle, hardware costs took a drastic drop, and have been dropping ever since. The cost of producing software has, at the same time, risen for two reasons: personnel costs have continued to rise and software requirements have become more complex. A larger set of skills is now required to produce instructional software. Because it is instructional material, expertise in instructional design, graphic arts, and curriculum are needed in addition to computer programming. The motivation for networks of microcomputers in the second cycle is the sharing of the software cost by spreading the use of a single copy over many student stations. As more is demanded of software instructionally, the design and development become more complex. It is software that carries the instructional message, and instruction is a complex process. It is difficult to see how software can become less expensive over time, since all the factors seem to argue for an increase. Hence, network systems may become more important in school computing facilities.

In examining the characteristics of software at various stages, one can see change and improvement. Dividing the characteristics into three categories of subject matter content, instructional process or pedagogy, and technical characteristics, we can see that in the latter, improvement has been steady. As new hardware capabilities such as color, graphics and increased RAM space have come along, software developers take advantage of them. Also, software development procedures for micros have become as organized as they are for mainframes, and there are fewer bugs in software than in the past. Most software in 1985 looked much better technically than that in 1980 or 1975. It is likely that trend will continue.

In the category of content, increases are seen in the quantity of subject areas and topics covered. It is estimated that there are 9,000 or 10,000 instructional programs available for micros in 1985, compared to 1,000 or

2,000 in 1980. Whereas much of the 1980 software focussed on mathematics, now a wide range of subjects is addressed. However, it is still not enough to support intense classroom use of computers in many subjects and levels. The effort has been bolstered by the entry of most major textbook publishers into software development. This trend can be expected to continue. However, it will follow textbook development and priorities for two reasons. First, states are beginning to link software requirements to textbook adoption and selection. Second, the return on investment for publishers is so low that many might discontinue development except for the importance to textbook sales of enhancing them with computer-based student activities. In addition to quantity improvements in content covered we can see that fewer mistakes are being made and hence the quality in terms of accuracy has improved. Most developers now involve subject area personnel in the development process. Rarely is it now the case that a lone computer programmer carries the whole development process out, regardless of his or her subject background. We can assume that content quantity and quality will continue to improve gradually.

It is in the area of instructional characteristics that most software has been criticized. Some see improvements while others do not. During the 1970's and into the 1980's, drill and practice software was dominant. In the last few years, interest in other instructional approaches has increased and much attention is focussed on simulation, gaming, and formats which are open-ended and require higher order thinking skills. Some of the hardware advances will aid in the development of such software. More complex software requires the additional RAM and higher processing speeds which are coming, and increased graphics and color capabilities are helpful. Also, the massive databases possible through CD-ROM will support instructional activities of an inquiry nature. Software improvements, while slow, are nonetheless real and can be expected to continue. We should expect in 5 years time to be able to provide comprehensive computer support for instruction in many subject areas at all levels 1 through 12. The primary factor retarding this advance is that if profits are not sufficient, the publishers may withdraw or reduce their effort.

CONCLUSIONS

The direction of computer hardware developments seem to bode well for the needs of Alaskan education. The low population density and geographic distribution and isolation of schools should mean they will benefit greatly from the ability to store large databases on small disks contained in and accessed in the classroom. The reduced need for telecommunications to access data in an age when such data is becoming important should be an economic benefit.

The development of software to address more subjects at more levels should be the major software benefit for Alaskan schools. The number of different topics and levels required to be taught in any day by a teacher outside the urban areas is so great that attention to individuals is difficult. The more supplementary instructional tools which are available, the richer will be the student's experience and the better will be the teacher's ability to handle the diversity.

The other benefits of future developments should be as applicable to Alaskan schools as to schools anywhere. Instructional stations of higher capability at lower cost should make it possible to acquire and utilize more computers. Recognizing the slower rate of software development compared to hardware, and that software is crucial to broader and more successful use of computers, it would be good strategy to consider how the state could assist in increasing the quantity and quality of software. Perhaps seeking partnerships with publishing companies to move their development in directions consistent with Alaskan needs should be considered.

The development of inexpensive lap computers or other configurations different than the standard desk top stations should provide many instructional advantages, particularly if they enhance an individual student's ability to proceed in directions of individual needs whether the student is at school or home. If producers can be convinced to package major instructional systems for topics such as basic skills in a lap computer configuration, the possibility is for a student to easily carry a major component of their educational process to home, school or other place of study.

It is to be hoped that the field of computer education does not repeat a cycle starting over with each new configuration at a minimal level of storage and gradually increasing. It is now known that we need as much to start with as the previous configuration ended with, and progress demands that approach.

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