ADDRESSES AND CONTRIBUTED PAPERS

COMPUTERS, EDUCATION, AND ARTIFICIAL INTELLIGENCE

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Introduction

When large "maxicomputers" began to appear in the 1960s, we appreciated their value in banking, in airline reservation systems and in many other areas. But for educators they were far removed from our daily activities and could be easily ignored. Today more powerful maxicomputers, the appearance and spread of the totally new microcomputer, and a growing diversity of uses and users are causing a true Computer Revolution in our society. What the Industrial Revolution did for our physical abilities, the Computer Revolution is doing for our minds. At times I wonder how, if they were alive today, outstanding people like Martin Luther King or Gandhi or Darwin or Leonardo da Vinci would be using computers, and for what!

An important difference between the two revolutions is that the Computer Revolution is happening faster, taking only years instead of centuries. While it is called the Computer Revolution, more than just computers in the narrow sense are involved. It also includes telecommunications, television as a two way communications device, and much more. Telematics is a term frequently used to include this wide diversity of machines, data, and sensing devices. Computers also have become a convenient scapegoat in society. If a power or credit card company makes an error in our bill, it is the computer's fault. We know that a true computer error is a very unlikely explanation, but it fills a necessary psychological function.

One way to appreciate how important computers have become in society is to consider what would happen if suddenly all computers ceased to function and could not be fixed or replaced. Requests for instant credit could no longer be filled. Airline reservations and traffic control would have to be done manually, greatly reducing the total number of flights. Our salary checks would be slower in arriving. Computer based patient monitoring would cease. Many military weapons would be unusable. The list is almost infinite.

Closer to our careers, computers in education would disappear, much like biological extinction. The question of whether this would be a good or bad event would no doubt bring a mixed response from educators. Regardless of how one feels about educational computing, it plays a significant part in American education today. Consequently, as professional educators we are mandated to become familiar enough with the subject to make sound decisions for ourselves about its role in the education of our particular students.

In this paper I will examine the current status of computer assisted education and one of its possible future directions. To do that I first will review some basic concepts of computers and of education.

Computers

Computers have been called many things, some of them unprintable. I suggest the following as a simple, optimistic, nonthreatening, operational definition: computers

are an extension of our minds and senses! And in education they also are extensions of the minds and senses of our students. A corollary emerges from such a definition: computers can never replace good teachers; they can only enhance their value.

Computers are not just the hardware, the physical machines themselves. Rather, a computer system has three essential components: hardware; software; and people. Software refers mainly to the programs written to tell the computer hardware what to do. People are us! But for educomputing the two most important groups are instructors and learners. Decisions made about computers in education must consider the specifics of all three components of the computer system. Failure to do so has been costly and frustrating. Perhaps the most common example is when a college administration purchases a series of microcomputers from the company that submitted the lowest bid to supply the hardware. Joy turns to sorrow when the administration learns that few if any educational programs exist for that particular machine, and the people in that particular educational computing system (the students and educators) are unable to create them.

The fields of computing and of educational computing are in exponential phases of growth. No characteristic is changing linearly over time, be it the possible number of additions per second, the number and diversity of users and uses, or any other property. It is like every day we find that we can jog faster and faster.

Education

Most of us are professional educators, a noble and essential calling. But do we really educate? Do we educate effectively? How do we know? Do we or our administration measure it by the popularity poll of Teacher Course Evaluations administered to students?

Do we consider holistic aspects of education? That is, do we consider not just the cognitive intellectual backgrounds and goals of our students but also the affective domain—the emotional attitudes and motivation towards the subject, both of our students and of ourselves?

What do we try to maximize in our courses? Is it test scores, student excitement about the topic, valuable reasoning skills, or?

What type of diagram would each of us draw to summarize the pedagogic components of one of our courses? Would items like lecture and textbook emerge as the most important sources of learning? If you asked each of your students to do the same, would they draw the same diagram? More importantly, would they indicate the same components as being the most important in their learning? For example, you might think that your lectures are the most important component, but they might say it is other students and the laboratory. Only after such a systems diagram has been created specifically for a particular course can we decide on a sound basis if computers can enhance education in it. Computers can be considered as just another component in such a diagram. But they are special since they have the potential to affect almost all others to a very significant degree.

Computers in Education

Overlapping and redundant terminology is unavoidable in any rapidly developing field. Educational computing is no exception. Let me define several commonly used terms, because each relates to a different and important concept. I use "computers in education" as a neutral, general term to encompass all elements of educomputing. It has three major components: computer awareness; computer literacy; and computer assisted education.

"Computer awareness" is an appreciation of how computers affect us in our

everyday lives, both individually and as members of society. Grocery store checkout scanners, computerized brain scans, traffic signal controls, are three specific examples.

"Computer literacy" is the ability of a particular person to perform a particular task via computer. Let me emphasize that this may not require knowledge of a programming language such as BASIC. Examples are a professor or student writing a program to simulate exponential or logistic population growth, use of a word processing package to prepare term papers, or use of a test bank to prepare chemistry examinations. Some people include computer literacy as part of computer awareness, but this causes considerable confusion.

Finally, "computer assisted education" is the use of computers to teach or learn a subject other than computing. So computers in the physics laboratory or in an earth sciences lecture are examples of computer assisted education. Relationships among the three components of computers in education can be summarized using a Venn diagram (Figure 1). Focusing on computer assisted education, it can involve a topic in basic science and require no computer literacy beyond how to follow instructions given on the computer screen. Alternatively, students may be asked to carry out a simulation of possible outcomes from a nuclear power plant accident. This would involve an overlap with computer awareness (Figure 1, area 1). Another possibility would require students to create a simple program to evaluate the effect of different growth coefficients on population size after 25 generations. This task would involve computer literacy (Figure 1, area 3). Finally, certain activities in computer assisted education can require all

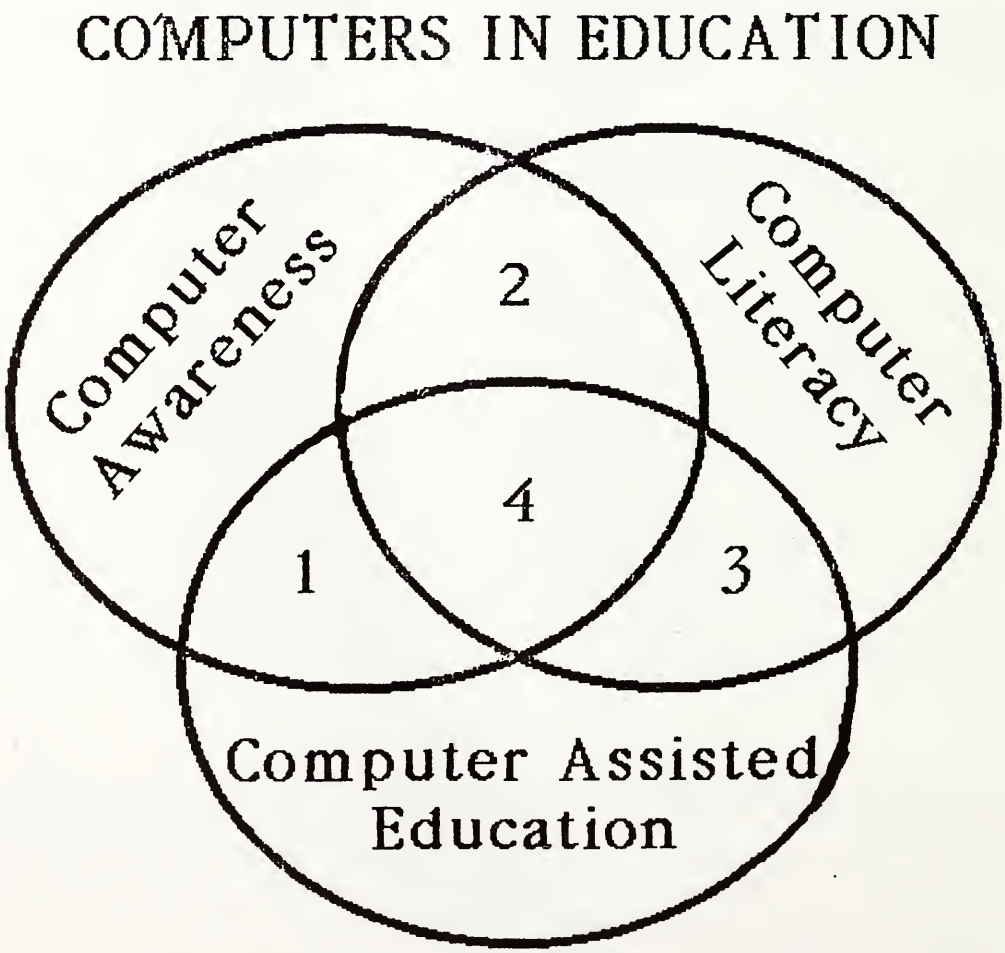

FIGURE 1. *The three aspects of computers in education.*

three components of computers in education (Figure 1, area 4). For example, each group of students might be asked to construct and analyze a model of endangered species to suggest good management strategies.

Given an understanding of computers, education and computers in education, the essential question still remains: can computers enhance education? This is really too general a question. Important but more specific questions include the following: can computers make a subject more attractive, allowing students to internalize it; can they help students learn a topic more quickly or deeply, i.e., to climb Bloom's cognitive ladder faster and higher.

Let's consider the lecture component of a course. Why are they often boring to students? The major reason is because the majority of students frequently remain totally passive throughout the lecture period. No matter how good the lecturer, most students are still involved in only one way communication. Yet we ourselves know that we only really learn a topic when we have to teach it. And the reason is that we are totally active in the process. What this means is that ultimately computers may allow educators to carry out more effectively the essential roles of facilitator and expert, doing what we should—taking up where the computer and any other educational devices leave off.

In the usual lecture only course, students never get the chance to be tutors. In such cases, even without computers, the following procedure might be valuable. Take the last ten minutes of every lecture period, lock the doors, have students simply turn around to arrange themselves in groups of three or four, and let them teach each other what was said by the professor in the first forty minutes. One important advantage is that such a procedure would correct those instances when students truly believe they understand what was said in lecture but in fact do not.

Today computers are used in many ways in education; literature retrieval; data retrieval; data accumulation; online control of experiments; statistical analysis; graphic summarization; simulation and modeling; decision making; drill and practice; tutorials; test generation and administration; course management; and word processing. The list grows every year.

Computers are used in the above ways because educators believe they will enhance learning. Any other reason is insufficient. More specific reasons for using computers in education include the following: increased effectiveness of teaching what we already teach; increased students' interest in the subject matter; an increasingly active role for students; a decrease of boring tasks associated with learning; increased ability for students to learn at their own pace (and according to their own particular diurnal rhythms!); and an increase in the level of individualized instruction. This last reason reveals a paradox—that the allegedly impersonal computer might be able to provide a more personal education. A corollary is that computers could help provide a better education to a heterogeneous group of students.

Artificial Intelligence

Before considering the future of computers in education, let's review some basic ideas of artificial intelligence. Its use in education promises to be as important as the computer itself. Artificial intelligence is the ability of a machine to exhibit intelligent behavior. This begs the question of what constitutes intelligent behavior, and each of us probably would indicate the boundary of intelligence differently. For example, does a word processing program exhibit intelligent behavior? Is a graphing program that includes automatic scaling of a graph's axes intelligent? Does a disease diagnosis program have intelligence?

Perhaps the most constructive view is not to consider intelligence as a yes/no

character, i.e., that a person or machine either has or does not have intelligence. It seems more useful to consider intelligence as a continuum, such that a particular computer program, just as individual people, may exhibit various degrees of intelligence depending on the particular skill or intelligence criterion being used. Currently the field of artificial intelligence reserves the term artificial intelligence for programs that exhibit higher levels of cognitive behavior. Thus, a disease diagnosis program that just compared a set of a patient's symptoms against the known symptoms of a series of diseases would not be considered intelligent. On the other hand, one that incorporated expert physicians' procedural knowledge in addition to their factual knowledge would be considered intelligent.

Artificial Intelligence In Education: A Future Direction

Artificial intelligence in education is the use of intelligent computers to educate. For example, a program that simply asked a grade school student to solve simple subtraction examples would not be considered intelligent. But a program that could do the following would be considered intelligent: keep track of a particular student's mistakes

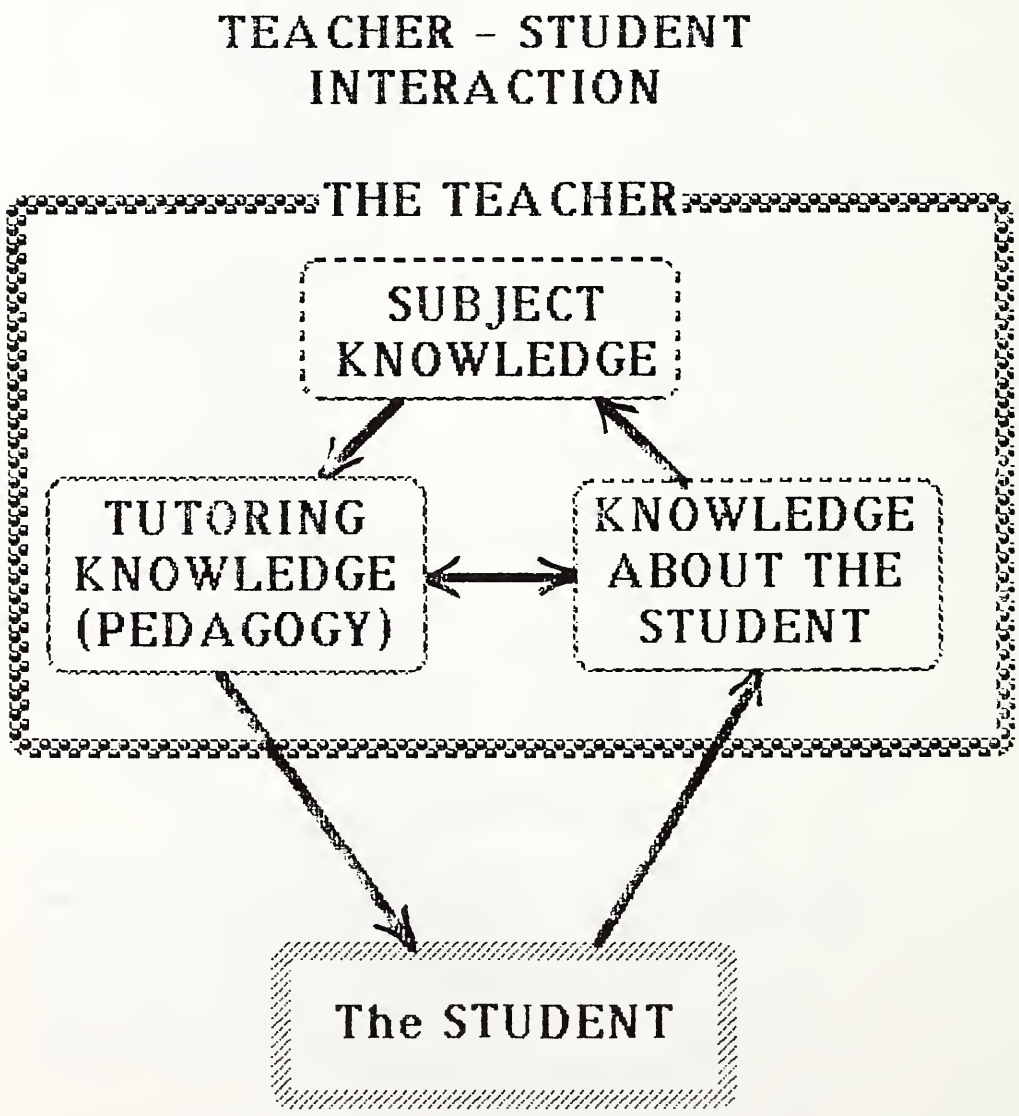

FIGURE 2. *A diagram of teacher-student interaction.*

over a series of subtraction examples; determine what particular type of error is being made; and provide customized remediation to help the student discover and correct the specific procedural mistake.

Let's paraphrase these ideas by considering what a teacher does. Figure 2 summarizes the interaction between a teacher and a student. Assume the topic is the subtraction problem described above, or the study of meiosis in organisms, etc. An effective teacher must have three types of knowledge: knowledge about the subject matter; knowledge about the particular student; and pedagogic knowledge sophisticated enough to help each student in the most effective way.

Figure 3 shows what an intelligent computer program must have to be able to exhibit intelligent behavior in education. Analogous with the teacher, it must have three types of knowledge: a model of the particular student's understanding of the topic being learned; expert knowledge of the topic for comparison with the student's knowledge; and the ability to tutor each student in the best way.

The similarity between Figures 2 and 3 is obvious. Does this indicate even more emphatically that the role of educators will decrease? No! On the contrary, I firmly

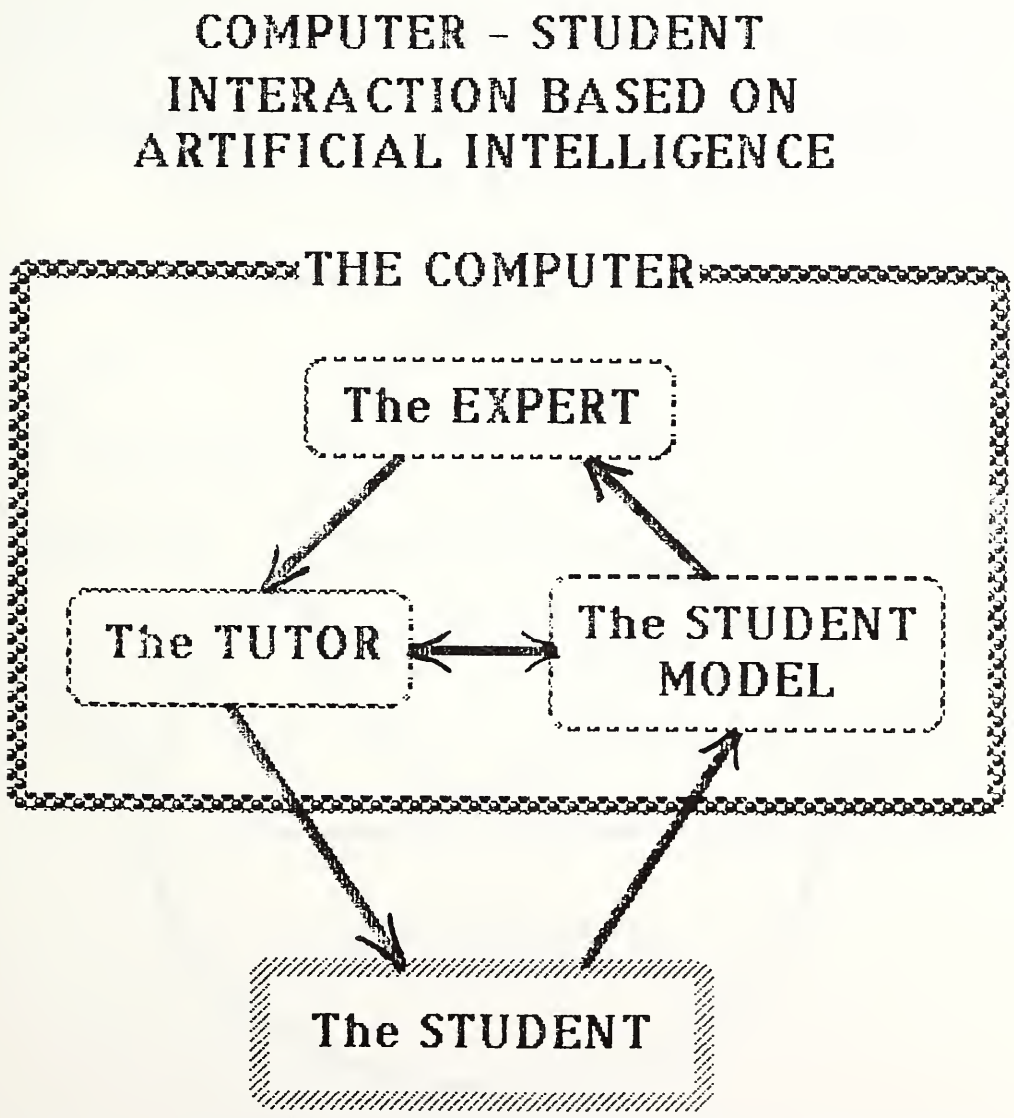

FIGURE 3. *A diagram of computer-student interaction based on artificial intelligence.*

believe that every advance in educomputing will underscore the value of educators and increase their roles for several reasons. First, viewing computers as another component in the educational system clearly requires a professional to integrate them with other components in a way that assures maximum learning. Second, computer programs will never be available for every topic covered in a course, with respect both to depth of coverage and in the format most appropriate to a particular class of students. Third, even if appropriate programs were available for all topics, few would exhibit high levels of pedagogic intelligence; the time and other resources needed to create such programs would be a serious limitation. Finally, just as with textbooks, many programs become outdated as soon as they are available. Some PERSON has to fill that gap, and that person is the professional educator.

Educational Computing Today and Tomorrow

Let's summarize where educational computing is today and where it might be in the future. Certainly we can expect continued improvements in hardware, due mostly to microprocessor technologies that allow more computer power to be put on one computer chip. Almost all microcomputers used in education today are based on an 8-bit chip. One exception is the Macintosh with a 32-bit architecture. That is an increase

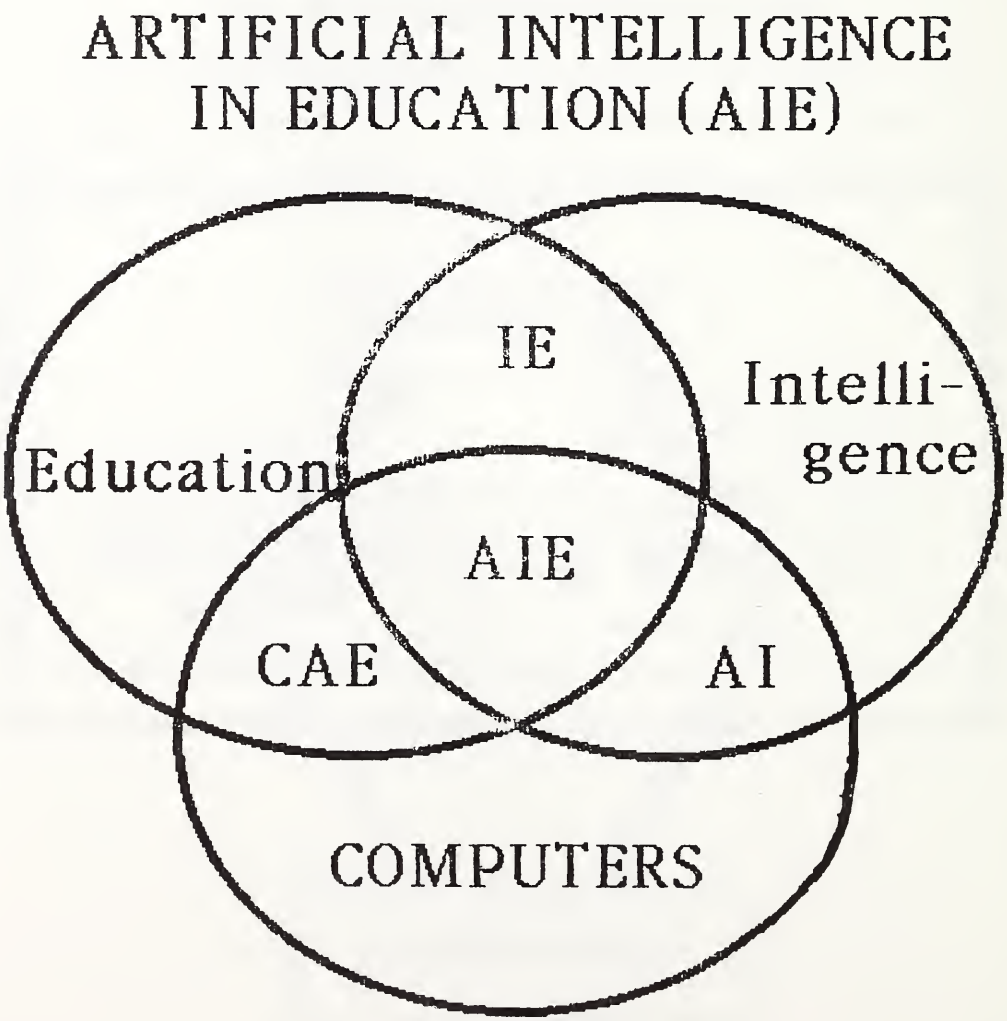

FIGURE 4. *Artificial intelligence in education.*

of two orders of binary magnitude. When most educational computers have a 32-bit or higher foundation, expect parallel increases in software.

More important than hardware are the changes in educational software. Figure 4 relates present and future developments in programs for education. Currently many educators are involved with Computer Assisted Education (CAE). At the same time artificial intelligence (AI) is a very active area of computer research. Several current education programs exhibit high levels of intelligence, but they are prototypes, not used widely, and require larger machines than those found in the classroom. Nevertheless, we can expect that the triple overlap of computers, education, and intelligence, i.e., Artificial Intelligence in Education (AIE) will become more common and more important. One other overlap area appears in Figure 4, that between Intelligence and Education (IE). It asks us to consider just how intelligently we are educating now, even without the computer. I do not believe or mean to imply that there is no intelligent education without computers. But Figure 4 might motivate each of us to consider how we could increase intelligent education in our particular situation, regardless of whether computers are being used.

Periodically someone asks if computers in education are just a fad, like teaching machines and simple uses of television. From my perspective of almost twenty years in education I can say it is not just a fad and will not go away. One reason is that the programs will be smarter, but another reason is that more and more educators will accept intelligent computers both as powerful teaching aids and teaching aides!