LECTURE 22

COMPUTER AIDED INSTRUCTION - CAI

Because computers were early installed in many Universities it was natural that the question of computer aided instruction, (CAI),would arise and be explored in some depth. Before we get to the modern claims it is wise to get some perspective on the matter.

There is a story from ancient Greek times of a Mathematician telling a ruler that there were royal roads for him to walk on, and royal messengers to carry his mail, but there was no royal road to geometry. Similarly, you will recognize that money and coaching will do only a little for you if you want to run a four minute mile. There is no easy way for you to do it. The four minute mile is much the same for everyone.

There is a long history of people wanting an easy path to learning. Aldous Huxley, in his book Brave New World discusses the idea of learning while sleeping via a microphone under your pillow telling you things while you sleep, and he exposes the severe limitations of it. During my years at the Bell Telephone Laboratories the Dianetic movement arose and promised that it could "clear" your brain of all its errors and that then you would be able to reason perfectly. There are still Dianetic Institutes, but the consensus is against them - particularly as the people produced by them seem not to have dominated any sector of human activities, let alone all sectors. Another organization promises to reveal the secrets of the ancients (who were, some how, so much smarter than we are now). We have endless ads for speed reading, speed learning, etc., all of which promise, in one way or another, to greatly improve your mind without the hard labor that most of us have to put in if we want to succeed. The test of all the previous proposals is that not one of them has, as yet, produced a significant number of exceptional people, (that we know of at present). As Fermi said about the Extra Terrestrial Intelligence and UFO people, "Where are they, and why have we not met them?"

Hence all of past history with its many, many claims of easy learning speaks eloquently against the current rash of promises, but it cannot, of course, prove that some new gimmick will not succeed. You need to take a large grain of salt with every such proposal - but there could be new things that the past did not know, and new tools like the cheap computers now available that were not available then, which could make the difference. Regularly I read or hear that I am supposed to believe that the new gimmick, typically these days the computer, will make a significant difference in spite of all past promises that have apparently failed miserably. Beware of the power of wishful thinking on your part - you would like it to be true so you assume

that it is true!

There is another important factor, known as the Hawthorne effect, that it is necessary to explain. At the Hawthorne plant of Western Electric, long, long ago, some psychologists were trying to improve productivity by various changes in the environment. They painted the walls an attractive color, and productivity rose. They made the lighting softer and productivity rose. Each change caused productivity to rise. One of the men got a bit suspicious and sneaked a change back to the original state and productivity rose! Why? It appears that when you show that you care then the person on the other end responds more favorably than if you appear not to care. The workers all thought that the changes were being made for their benefit and they responded accordingly.

In the field of education, if you tell the students that you are using a new method of teaching then they respond by better performance, and so, incidentally, does the professor. A new method may, or may not, be better, indeed it may be worse, but the Hawthorne effect, which is not small in the educational area, is likely to indicate that here is a new, important, improved teaching method. It hardly matters what the new method is, its trial will produce improvements if the students perceive it as being done for their benefit. Thus the Hawthorne effect vitiates most educational experimentation. You will recall my earlier discussion, Lecture 20, of the necessity of "double blind" experiments in medicine - it is the same in all situations where the respondee senses that special treatment and special care are being given. Those who later measure the effects must also be kept in ignorance of who did or did not get the special treatment! It is a fact of life in all such experimentation, but it is usually ignored. Hence you should never believe the results of carelessly done experiments when they involve humans. The prestige of the experimenter, the elaborateness of the equipment, the cleverness of the data reduction, and especially your desire to believe, should not be allowed to sway you. Again, that does not mean that there is nothing there, only that you need to be very, very careful before acting on such experiments.

The Hawthorne effect strongly suggests that the proper teaching method will always to be in a state of experimental change, and it hardly matters just what is done, all that matters is that both the professor and the students believe in the change.

Let me turn to some of the past history of the use of computers to greatly assist in learning. I recall that in 1960 while I was at Stanford on a sabbatical, there was a "grader program". Any problem that the professor wanted to assign to the class in a programming course required the professor to give a correct running program to solve it, the names of the input variables, the ranges in which the input numbers could occur, and also a limit for the roundoff of the output numbers to be acceptable. When the students felt that their program was ready for submission, they called the grader, gave their identification,

and the machine generated some random admissible input, ran both their and the professor's program, and compared the results. Each output number was, "Right or wrong." Such a grader can easily incorporate the time of compiling and the time of running, which are mere numbers, and still be required to make no judgment on style.

The method is flexible, easily adapted to changes in the course and in the specific exercises assigned from year to year. The program keeps a record in a private data base of the professor, and on demand from him gives the raw facts, leaving any evaluation to the professor. Of course class averages, variances, distribution of grades, etc., can all be supplied to the professor from his data base, if wanted.

When I visited Stanford a couple of years later I asked about the grader program. I found it was not in use. Why? Because, so they said, the first prof who had got it going left and a change that had been made in the monitor system would require a few changes in the program! Diligent watching and asking shows that this is very typical on many campuses. The machine is programmed to greatly assist, apparently, the professor, but the program is soon forgotten.

Let me turn to the project PLATO done by a friend of mine at the University of Illinois. I regularly met him at various meetings, and once on a long airplane ride, and every time he told me how wonderful PLATO was. For example, once he said that at the same time Plato had a pupil from Scotland, one from Canada, and one from Kentucky. I said that I knew that the telephone company could do that, and what he was saying was totally irrelevant to whether or not PLATO was doing a better job than humans did. He never, to my knowledge, produced any serious evidence that PLATO did improve teaching in a significant fashion - above what you would expect from the Hawthorne effect.

One claim made was that the student was advanced about 10% along the education path over those who did not use the system. When I inquired as to whether this meant that it was the same 10% shift all through the educational system, or whether he meant 10% on each course, compound interest as it were, he did not know! What had he done about the Hawthorne effect? Nothing! So I do not know what was or was not accomplished after spending the millions and millions of dollars of Federal money.

Once when I was the chief editor of the ACM Publications a programmed book on computing was submitted for publication. A programmed book regularly asks questions of the reader, and then, depending on the response, the reader is sent to one of several branch points, (pages). In principle the errors are caught and explained again, and correct answers send the reader on to new material. Sounds good! Each student goes at their own pace. But consider, there can be no back tracking to find something you read a few pages ago and are now a bit fuzzy about where you came from or how you got here. There can be no organized browsing through the text. It really isn't a book, though from the out-

side it looks like one. Another terrible fact is that carefully watching the students to see what happens in practice has shown that a good student often picks what they know is the wrong answer simply out of either boredom or amusement to see what the book will say. Hence it does not always work out as it was thought it would; the better students do not necessarily progress significantly faster than the poorer ones!

I did not want to reject programmed books on my own opinion, so I went to the Bell Telephone Laboratories' psychology department and found the local expert. Among other things he said was that there was to be a large conference on programmed books the following week, and why didn't I go? So I did. On the opening day we sat next to each other. He nudged me and said, "Notice that no one will ever produce any concrete evidence, they will only make claims that programmed texts are better." He was exactly right - no speaker had anything to offer in the form of hard, experimental evidence, only their opinions. I rejected the book, and on hindsight I think that I did the right thing. We now have computer discs that claim to do the same thing, but I have little reason to suspect that the disc format makes a significant difference, though they could backtrack through the path you used to get there.

I have just given some of the negative side of CAI. Now to the positive side. I have little doubt that in teaching dull arithmetic, say the addition and multiplication tables, a machine can do a better job than a teacher, once you incorporate the simplest program to note the errors and generate more examples covering that point, such as multiplying by 7, until the point is mastered. For such rote learning I doubt that any of you would differ from my opinion. Unfortunately, in the future we can expect that corporations and other large organizations will have removed much of the need for just such rote learning (computers can often do it better and cheaper) and employment will usually require judgment on your part.

We now turn to airplane pilot training in the current trainers. They again do a better job, by far, than can any real life experience, and generally the pilots have fairly little other human interactive training during the course. Flying, to a fair extent, I point out, is a <u>conditioned response</u> that is being trained into the human. It is not much thinking, though at times thinking is necessary, it is more training to react rapidly and correctly, both mentally and physically, to unforeseen emergencies.

It seems to me for this sort of training, where there is a conditioned response to be learned, machines can do a very good job. It happens that as a child I learned fencing. In a duel there is no time for local thinking; you must make a rapid conditioned response. There is indeed a large overall planning of a duel, but moment to moment it must be a response that does not involve the delay of thinking.

When I first came to the Naval Postgraduate School in 1976

there was a nice dean of the extension division concerned with education. In some hot discussions on education we differed. One day I came into his office and said that I was teaching a weight lifting class (which he knew I was not). I went on to say that graduation was lifting 250 pounds, and I had found that many students got discouraged and dropped out, some repeated the course, and a very few graduated. I went on to say that thinking this over last night I decided that the problem could be easily cured by simply cutting the weights in half - the student in order to graduate would lift 125 pounds, set them down, and then lift the other 125 pounds, thus lifting the 250 pounds.

I waited a moment while he smiled (as you probably have) and I then observed that when I found a simpler proof for a theorem in Mathematics and used it class, was I or was I not cutting the weights in half? What is your answer? Is there not an element of truth in the observation that the easier we make the learning for the student the more we are cutting the weights in half? Don't jump to the conclusion that I am saying that poor lectures should be given because then the students must work harder. But a lot of evidence on what enabled people to make big contributions points to the conclusion that a famous prof was a terrible lecturer and the students had to work hard to learn it for themselves! I again suggest a rule:

What you learn from others
you can use to follow;

what you learn for yourself
you can use to lead.

To get closer to the problem, to what extent is it proper to compare physical muscles with "mental muscles"? Probably they are not exactly equivalent, but how far is it a reasonable analogy? I leave it to you to think over.

Another argument I had with this same dean was his belief that the students should be allowed to take the extension courses which were under his wing at their own pace; I argued that the speed in learning was a significant matter to organizations - that rapid learners were much more valuable than were slow learners, (other things being the same); that it was part of our job to increase the speed of learning and mark for society those who were the better ones. Again, this is opinion, but surely you do not want very slow learners to be in charge of you. Speed in learning new things is not everything, to be sure, but it seems to me that it is an important element.

The fundamental trouble in assessing the value of CAI is that we are not prepared to say what the educated person is, nor how we now accomplish it, (if we do!). We can say what we do, but that is not the same as what we should be doing. Hence I canonly give more anecdotes.

Consider the claims that graphics well done would be of great assistance to learning basic concepts. Sounds good, but

consider the story I told you about my friend Kaiser, and how having learned filter theory in terms of time and voltage, he could not cope, in spite of directions, with the independent variable being energy. Again, Kaiser is a very smart person, but his education had restricted his view of the use of what he had learned. The better we inculcate the basic idea with the pictures drawn by the professor, the more we prevent the student from later extending the ideas to completely new areas not thought of by the professor (and put into the grapahic display).

Let me tell you another story about the transfer of training, as it is called - the use of ideas from one place to another. During the very early part of WWII I was teaching a calculus course at an engineering school in Louisville. The students were having trouble in a course in thermodynamics taught by the dean of engineering, who was an ex-submarine commander and who scared the students. With the dean's permission I visited a class to see what was happening. He put on the board, at one point,

$$\text{INT}[d\theta/\theta]$$

and asked what it was, and no student knew. The very next hour in my class across the hall I wrote

$$\text{INT}[dx/x]$$

and they all knew immediately that it was log x plus a constant. When I

$$\text{INT}[d\theta/\theta]$$

they again knew. "Why," said I, "did you not respond with that in the dean's class last hour?" The fact is, what they knew in one class at one hour with one professor did not transfer to the another hour in a room across the hall with another professor. Sounds strange, but that is what is known as the "transfer of training" - the ability to use the same ideas in a new situation. Transfer of training was a large part of my contribution to Bell Telephone Laboratories - I did it quite often, though of course I do not know how many chances I missed!

Let me turn to the calculus course I have often taught at the Naval Ppostgraduate School, though I had formed this opinion years before. Students are remarkably able to memorize their way through many math classes, and many do so. But when I get to analytic integration (I give the students a function and ask for its indefinite integral) there is no way they can memorize their way through the course the way I teach it. They must learn to recognize

$$\text{INT}[dx/x] = \log x + C$$

in an almost infinite number of disguises. For the first time in their career they are forced to learn to recognize forms independent of the particular representation - which is a basic feature

of Mathematics and general intelligence. To take analytic integration out of the course, or transfer it to routines in computers, is to defeat the purpose of a stage of learning something that is essential, in my opinion, unless something of equivalent difficulty is put in. The students must master abstract pattern recognition if they are to progress and use Mathematics later in their careers.

A very similar error was made years ago when I was a student at the University of Chicago. The Education Department ran an Elementary School for research purposes. They had found that students learn to read by syllables not by letters, and so they decided to skip teaching the alphabet and get on to the real reading. Which they did. Things went on quite well until late high school when it was found that not knowing the alphabet thoroughly the students could not effectively use dictionaries, phone books, etc. At their age then it was practically impossible to make them so overlearn the alphabet that they could use such information sources easily. Thus I am wary of proposed changes until the consequences have been followed out carefully through long term predictions of all necessary needs for the material they are now going to omit.

In summary, as best I can, clearly in low level conditioned response situations, typically associated with training, I believe that computers can greatly add in the learning process, but at the other end, high level thinking, education, I am very skeptical. Skeptical, mainly because we ourselves do not understand either what we want to do, nor what we are presently doing! We simply do not know what we mean by "the educated person", let alone what it will mean in the year 2020. Without that knowledge, how am I to judge the success of any proposal that is tried? Between low level training and high level education there is a large area to be explored and exploited by organizations outside the universities as well as inside. I will discuss at great length in Lecture 26 the point that rarely do the experts in a field make the significant steps forward; great progress generally comes from the outside. The role of CAI in organizations with large training programs will increase in the future as progress constantly obsoletes old tools and introduces new ones into the organization that are generally more complex technically to use.

Consider the programs on computers that are supposed to teach such things as business management, or, even more seriously, war games. The machines can take care of the sea of minor details in the simulation, indeed should buffer the player from them, and expect good, high level decisions. There may be some elements of low level training that must be included, as well as the higher level thinking. We must ask to what extent it is training and to what extent it is education. Of course, as mentioned in the three Lectures on simulation, we also need to ask if the simulation is relevant to the future for which the training is being given. Will the presence of the gaming programs, if at all widespread, perhaps vitiate the training? You can be sure, however, that even if the proposers cannot

answer these questions, they will still produce and advertise the corresponding programs. You may be a victim of being trained for the wrong situations!

A few hundred years ago the standard higher education was learning to read, write, and speak Latin, along with a smattering of Greek and a knowledge of the Classics. This was the basic education with which Englishmen, for example, went out and created an empire. Our present education has very, very little in common with the classical one. I suggest strongly that the future education will have as little to do with the present education as the present education has with the classical education. Tinkering with small changes in our present educational system will not meet the problem we face in preparing the students for the year 2020 when lap top computers are universally available along with immense storage capacity for information and ability to process data. Without a vision of what kind of education will be appropriate at that time how are we to evaluate proposed CAI projects? Just because something can be done, especially using computers, does not mean that it should be done. We must create a vision of what the educated person will be in the future society, and only then can we confidently approach the problems that arise in CAI.