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THE DILEMMA OF TEACHER TRAINING

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> "Would you tell me please, which way I ought to go from here?"
>
> "That depends a great deal on where you want to go to," said the Cat.
>
> "I don't much care, where," said Alice.
>
> "Then us doesn't matter which way you go," said the Cat.
>
> (from *Alice in Wonderland*, Lewis Carroll)

In 1957 the Soviet Union put up the first earth satellite, Sputnik I. For education in the United States this was a traumatic event. Until that time many (but not all) people, including the popular press, commonly denounced Soviet science as ineffective. The fact that it achieved this major technological development, visible in many parts of the country, before we did led to much trauma about the quality of science education in the United States.

One reaction was an organized curriculum effort in American education, the major such event in our history, mostly funded by the United States government, It lasted about 15 years. The curriculum efforts were well funded; many of the courses developed during this period cost millions of dollars to produce. I would estimate that close to one hundred million dollars were spent in these extensive efforts—more by today's prices. Major individuals participated in their development, including major figures in science, mathematics, and education. The concentration was on the east coast, but it was a nationwide effort. Books were the most common product, with some production of films and other items.

Some efforts were in elementary science, including such major products as the Science Curriculum Improvement Project (often called SCIS) at the University of California, Berkeley, directed by Robert Karplus. A similar project was Elementary Science Study at MIT. These courses were very different than existing practice at the elementary level, with much more emphasis on the processes of science, and much less emphasis on memory of pieces of information. Mathematics courses also were developed, with new approaches. High school courses were developed, and even a few university courses. I was involved in one of these, the Harvard Project Physics course for secondary school.

One project, Man a Course of Study, a fifth grade sociology course, brought this large curriculum development effort to an abrupt end, for political reasons. This was a very interesting story, but not relevant to this paper. The problem has made funding major curriculum development difficult even to this day.

Although many of the resulting courses were widely praised by scientists and educators, most of the products were not successful in practical usage. Only the courses produced by the Biological Sciences Curriculum Study group are in common use today. This well-funded failure led to much agonizing about what went wrong. Some of this thinking appeared earlier, but we are still hearing the reasons for lack of success. Probably everyone “knows” why the curriculum failed. One reason commonly cited for this failure was of considerable importance at the time, and is the primary concern of this paper. Since these new courses were different than older courses, in both content and in learning style, it was believed that teacher training was essential to prepare teachers for this new task. With many of the courses, particularly the science and mathematics courses, the entire philosophy of what the student and teacher were supposed to do was strange to many teachers—different than their previous training.

A major effort in training teachers in these new courses took place. It is difficult to estimate the funds that went into teacher training for the new courses, since the funding came from so many sources. I have seen an estimate that teacher training costs for the post-Sputnik courses were seven times the cost of development, which would make the total over five hundred million dollars—a huge amount. But mostly the courses were not helped by this large effort. Teacher training was of variable quality, and often not effective. Most of the major post-Sputnik efforts died.

We continue with such efforts in training teachers for all of education. It is a major part of the educational funding of the National Science Foundation and other major federal agencies. Recently (2002) the National Science Foundation has awarded $240 million under the Math and Science Partnership (MSP) program, mostly for such training efforts in science and mathematics. The large PT3 program from the Department of Education was another recent example. But these efforts, even if successful, reach only a small percentage of the teachers, and therefore, students, in the United States. For example, the MSP grants are for only 24 centers.

Almost every new school movement and curriculum development in the United States is matched with a corresponding training activity. The recent elementary reading program from the Bush administration is an example. But, in spite of occasional glowing reports, it is seldom successful. Training teachers is a common problem with education generally. One might say it is the Achilles heel of education.

AN IMPOSSIBLE TASK

I wish to argue that in-service training for a sufficient number of teachers for new curriculum and learning methods is impossible by present means, and perhaps by any means. It is a myth to believe that we can effectively train enough teachers by present strategies. I am basing this argument primarily on the United States, but I believe that similar factors apply worldwide. This article does not consider pretraining of teachers, another similarly tremendous problem at this time. We do not have enough well-trained teachers, and the situation is not improving. Large numbers of students in a class is a result.

The central problem is numbers – too many people in this country (three hundred million) and on earth (six billion). With so many people who need to learn, our current systems for learning employ large numbers of teachers. In the United States there are now about three million teachers in 90,000 schools. We have about 50 million students, of ever-greater diversity.

Most of our thinking and strategies in education are based on older traditions when the numbers were much smaller. However, the numbers change everything, in ways that we are only beginning to understand. Others have noted this: "Sober thought also tells us that any suggestion that some two million teachers be retrained to change what they do in classrooms must be called wishful" (Hart, 1983).

We still spend enormous sums on in-service teacher training. Whenever something does not work, it is the recommended solution, just as with post-Sputnik development. Major organizations, both nationally and in the states, support this approach.

Currently, teacher training is being heavily touted for the use of the Internet in classes. An article in the *New York Times* July 3, 2000, reports that 95% of schools in the United States now have Internet connections. But Internet connections in schools very often do not lead to improved learning, not a surprise for many of us. Once more, the cry is that we should train the teachers about computers and the Internet. Once more, the teacher training is not adequate and not necessarily appropriate. A friend, about to get ten computers in her class, is in a course to prepare for this that is teaching her about bits and motherboards!

The results of teacher training are variable. Some teacher programs turn out to be effective, but this is a small number. As with much of education, we look for success and try to imitate it. But these good examples often depend on the existence of special situations, such as a superior teacher involved in the training, not duplicable elsewhere.

Often teachers are thrown in different directions every few years in these training programs. Several years ago California elementary teachers were told that they should integrate all subjects by establishing a common "theme" for all areas. A teacher I know chose "trails" as her theme. Many workshops for teachers stressed this approach. But this approach was quickly downplayed. Teachers are tossed around with little consistency from year to year, making a difficult task even more difficult. The current pressure for standardized testing further complicates this issue.

This variation in recommended practices is particularly bad with the critical areas of reading and mathematics in the elementary grades, where the battle for different approaches has gone on for a long time. The pendulum often swings, although it would seem that research could settle the issue. Often commercial forces are involved.

One approach that has been tried many times for training teachers is the "trickle down" approach, with a variety of names. It recognizes that we cannot reach all teachers directly with reasonable sums of money. The idea is that we will train a few teachers, and they will train other teachers at their schools. This may proceed for many generations. I was involved with one such effort involving educational technology for an important school district in southern California. I had a chance to talk to teachers in the third generation, after I had run the workshops for the first generation. I could find almost no relation between the two generations; nothing I did survived. I know of no large-scale evidence that the trickle down method works. It is not effective, it appears, as a method for reaching effectively large numbers of teachers.

Such training efforts are generally poorly evaluated, with regard to their long-range effects in improving learning. This is a common problem in many areas of learning, even though some agencies insist on built-in evaluation as part of the project.

Although the sums spent in this direction are large, they are never enough to reach all teachers effectively. We can wonder if they will ever be enough, given the numbers of teachers we are now faced with. It seems unlikely. So teacher education is a dilemma: We need continual training, but we cannot afford it. The situation is much worse in the poor parts of the world.

The pattern is as follows:

1. We develop new curriculum or new ideas for improving learning.

2. These do not work

3. The suggested solution is to train the teachers. Much money is spent.

4. This does not work.

5. No one investigates the costs of such failure.

We need to break this expensive pattern.

SOLUTIONS TO THIS PROBLEM

Given that current methods of addressing the problems of in-service teacher training are inadequate, how do we proceed? At least two ways seem possible for resolving this dilemma, both making effective use of the computer in a way that seldom happens today. Both are expensive at the beginning, but have possibilities for greatly reducing the long-term costs of learning. Both involve bold new directions, with little current experience, so both involve possible risks. They need major experimental efforts to demonstrate their effectiveness or lack of effectiveness. I see no other possibilities, but I welcome other ideas that try to address this major problem.

These two suggestions are related, in that they both involve extensive use of carefully prepared highly adaptive computer-based learning material. In the first case teachers are the learners. In the second the students are the learners. In both, distance learning is a natural delivery method. In both, the highly interactive units would adapt to the individual user. In both the learning material could be used anywhere at any time. Both can reach very large numbers. One of these suggestions for the future involves tutorial computer-based units for teachers, and one tutorial computer-based units for students.

Our recent book (Bork & Gunnarsdottir, 2001) explores computer-based tutorial leaning in much more detail. See also other papers of Alfred Bork (Bork 2000; 2001a), available on the web site under “Papers.” No new technology is required, but much new learning material must be generated.

1. Teacher training via interactive computer material

   Several years ago we made, at the University of California, Irvine, several unsuccessful efforts to obtain funding for computer-based learning units for teacher education in educational technology. Just before this we had conducted at Irvine an expensive teacher training session of this kind, taught in a conventional fashion, funded by the state of California. I did not think it was too effective, in spite of high costs and talented people involved. A quick calculation suggested that this was far too expensive to scale to all teachers in the state, the country, or the world, if we brought all these teachers to Irvine or to other similar places. Further, the manpower to do this for all teachers would not be available.

Hence we planned the proposals to do such training through the computer, using highly adaptive interactive learning units. Such an approach does not need to be training in educational technology, although it was natural, as computers will be required because of the subject matter. It could be done in any area.

Since the second suggestion also involves computer-based learning, I will postpone the discussion of the details of computer-based tutorial learning units, including how such material is developed. Later sections of this paper consider these details.

2. Computer-based tutorial learning for students

The second approach, students learning through interactive computer material, is a much more radical approach to teacher training, because it removes the need for most special training of the teachers. It is based on the possibility of distance learning, both in schools and informal environments, using a new form of learning material. It would require a radical change in learning, compared to our current situation.

It would allow, after sufficient learning material is developed, fewer teachers than we now need—excellent teachers playing different roles than current teachers. So the educational systems would be very different than those today. Learning would be tutorial, with the computer as the tutor.

As with the first suggestion, little material of this kind exists at present. In the next section the notion of tutorial computer-based learning is developed further. A later section discussed how to produce such material.

TUTORIAL LEARNING

Tutorial learning with human tutors has a long history. Because of the expense involved, it has always been used with a limited number of students. A skilled tutor works with one or several students. This situation does not resemble a lecture in any way. Often, as in the case of Socrates, the tutor proceeds by asking questions. With good tutors, this approach has proven to be a very successful learning strategy with students of all ages.

But tutorial learning with human tutors is far too costly to be possible for all learning, and we could never find enough skilled tutors for our large populations today. But it is possible and practical if the computer can serve the role of the tutor. We have been developing such computer-based tutorial units, on a small scale, for over 34 years at the Educational Technology Center at the University of California, Irvine. It requires no technology or learning approaches beyond that available today. It does require a new method of producing learning modules.

Here are the critical features of such learning modules. The "students" mentioned would be teachers in the first strategy suggested.

1. A very high degree of interaction

   Tutorial learning is active learning, student centered. Although computer material is frequently called interactive, to achieve the tutorial format we need a higher degree of student-computer interaction than is commonly found today. Interaction refers both to the frequency of interaction, and the quality of each interaction, as discussed in the next sections.

   One important consequence of active tutorial learning is that students can discover much of their knowledge rather than being told it. Examples will be given later.

2. No long speeches or video from the computer

   Frequent interaction means that the time between two student inputs should be short. Our testing in public libraries shows that the interval between two student inputs should be typically no longer than 20 seconds. Occasional longer intervals can be tolerated, for example to allow thinking time. Such a level of interaction allows us to individualize learning and to keep students at difficult learning tasks.

   This implies that computer and student "speeches" should be limited, as in human dialogs. So we do not want in interactive material long pages of text, as in most Web sites today, or long video sequences. The interaction should resemble a conversation, not a series of long essays.

3. Use students' natural languages for interaction

   The highest quality of interaction between two humans comes from our natural languages, the most powerful of all human tools. We seldom use pointing and multiple choice for human communication, so it should seldom be used with computers where interaction is important, a radical departure from today. This use of languages should be in both directions, computer to student and student to computer. The typical interaction in tutorial learning is a question from the tutor, here the computer, and a free-form response from the student.

   Student input should be in the native language of the student. Thus the student might reply to a question from the computer or ask a question, in English or in another language.

   Until recently such student input to the computer was possible only through typing. Now reasonable voice input is possible, with commercial available inexpensive speech recognition engines. Speaking is much more natural for humans than typing. With very young children, for example, in learning to read, it is the only approach possible.

4. Seek and help with individual student problems

   A key to learning with tutors is that the tutor is constantly seeking student learning difficulties. The tutor, human or tutor, needs to understand what problems are likely in each situation, and to find ways, usually through asking questions or giving problems to solve, to determine just what difficulties are to be found at each moment in learning.

   This is the principle pedagogical purpose of the frequent and high quality interactions just mentioned. Once such difficulty is located, the tutor proceeds to assist the student, checking to see if this assistance was effective. This is a continuing frequent activity in learning with tutors. We proceed always from what the student has already mastered.

The situation is similar to Vygotsky's idea of the zone of proximal development (Vygotsky 1962; 1979). At each point in learning, the student is ready to learn something more, in the zone. Frequent questioning allows the program to determine what is to be learned next.

Another way of viewing this helping process is that assessment is intrinsic to the learning material, occurring frequently and indistinguishable from learning. The student is not aware of taking tests; they are invisible, as learning and testing are blended. Testing is not distinguishable from the learning material. No cheating is possible, as happens with standalone tests. The purpose of such hidden testing is to determine what learning material should be presented next, not to assign grades. Tests are a negative factor on morale, so making them invisible is motivating. Ausubel, Novak, & Hanesian (1978) said, "The most important factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."

5. Store and use student information

   The program should frequently store information about the student, including learning problems. The designers make these choices. This information should be used to make decisions later in the program, and to review material that may still show weak student understanding. Thus decisions about what to do next will depend both on the recent student responses and on this stored information about the individual student.

6. Assure mastery for all learners

   This frequent mediation for student learning problems can be continued until all students learn the material fully, to the mastery level. Benjamin Bloom and his students (Bloom, 1984) showed that mastery is possible for almost all students with tutorial learning, in extensive experiments in the Chicago public schools. Several different learning sequences might be necessary to attain mastery for all, as not all students learn in the same way.

   Since all learners succeed, we can have a much more positive view of learning, encouraging lifelong learning. Students can proceed at their own paces, unique for each student.

7. Anywhere, Anytime, all students

   Presently we could reach large numbers using CD ROM or the Internet with such learning material, assuming computers are available to the students. In the near future, with satellites, special inexpensive computers, and solar powered computers, we can expect to reach almost everyone on earth.

   With distance learning the students can be anywhere. Learning can start and end at any time, with computers maintaining the records.

8. Distance learning

   Although tutorial learning modules could be used in traditional schools, universities, and training centers, most of the future use would reach people wherever they are. Students might be in homes, libraries, shopping centers, community centers, museums of various types, or in specially build learning facilities. They could be sitting on a swing in a yard, on the beach, or in the middle of a field of poppies. Distance learning liberates us from particular learning locations. Distance learning should be in a form that can reach very large numbers of students.

9. Peer learning

   A valuable learning approach involves students helping each other. Learning circles can be established either locally, or remotely electronically. Student records stored by the computer will assist this process. Occasionally, the computer units will ask for only a single student to be active and may rearrange the peer groups depending on the stored records.

10. Intrinsic motivation

    As students involved in distance learning will not be subject to the pressures and threats of standard classes, the learning materials must keep students interested in learning. Since everyone succeeds, the experience of learning can be enjoyable for all.

    Learning modules must be intrinsically motivating, keeping students at difficult tasks. A high degree of interaction will be of major help here, as active learning keeps students involved. A friendly positive approach will help greatly; we want help, not criticism. Other motivational approaches may be useful in holding attention, but the focus should be on learning rather than entertainment.

An important part of formative evaluation, part of the development process, will be to verify that the student's attention is maintained for long periods. In testing units in informal environments like shopping centers, where students are under no pressures to continue except their interests, we can record where many students leave the program and rework such sections until they are motivationally strong.

11. Very large numbers of students

    As noted, our world now has 6 billion people. By the middle of the century, the population is predicted to grow to 9 billion. Educational activities need to look toward very large audiences, many cultures, and various languages. Types of distance learning suitable for groups of 20 or 30, increasingly common in United States universities, will not be adequate to the needs of our society.

    Since very large numbers of people would be involved, the units would need to work without teachers, as well as with teachers.

IS SUCH LEARNING MATERIAL POSSIBLE?

The picture presented for tutorial computer-based learning is very different than most learning today. To some it will appear, I am afraid, as a fantasy. But I believe it is a realistic possibility for the near future. I begin with examples of such material from the Educational Technology Center at the University of California, Irvine.

As mentioned, we have been developing tutorial material for over 34 years, with mostly much more primitive equipment than now available. An example is the Scientific Reasoning Series, developed about a dozen years ago. There are, in the form sold by the IBM K-12 group, 20 hours of student material. Other material developed of a similar nature was not marketed commercially.

Examples from the Scientific Reasoning Series can serve to illustrate the possibilities for tutorial computer-based learning. In one, a program called Heat, the aim is to have all students invent the scientific concept of heat, starting with everyday knowledge about temperature. The program begins immediately, asking the student how she or he measures his own temperature and waits for a free-form answer. The student may need to be prompted if she or he does not answer in a reasonable time. Responses are sensitive to the student replies. The program continues in this questioning form for about 1 hour, one of the shorter programs in the Scientific Reasoning Series.

Other examples from the series show the possibilities of students discovering their own knowledge. One example is Families. The aim is to have students discover important scientific laws, such as Mendelian laws of genetics. The student makes experiments with imaginary animals, Nors. The computer is always watching what the student does with experiments on-line, and offers advice only when necessary. All students discover these important laws. This is one of the most difficult programs in the series, taking about 2 hours for a typical student.

In another program students discover the simple laws of electrical circuits, such as the need to have a closed circuit to light a bulb. This program is based on modules developed in the elementary science projects in the post-Sputnik development. They do not use equipment at the display, but students are urged to do this on their own. I remind the reader again that these were done many years ago on computers with far less capability than contemporary computers.

Another program, designed but without funds for implementation, helps students discover Newton's First Law of Motion. Much of what students are told in conventional courses can be discovered with such programs. The methods of learning used could consider any area. One of our projects at the University of California, Irvine, was Understanding Spoken Japanese (Yoshii, Milne, & Bork, 1992).

DEVELOPING TUTORIAL LEARNING MODULES

I will not discuss in full detail how such units are developed. The system we use was developed beginning 34 years ago at the University of California, Irvine. The computer science group at the University of Geneva, in Switzerland, joined with us about 10 years ago (Bork, Ibrahim, Milne, & Yoshii,1992). Current work is also proceeding at the California State University, San Marcos.

Creating tutorial learning modules requires a different development strategy than is common today. Four stages are involved: management, design, implementation, and evaluation. The most critical stage is design. The designers are very good teachers in the area involved, working in groups of about four. They do only the design; they do not program or construct media, for example; these activities are done partially by the computer and partially by skilled individuals in each area involved. The designers are responsible for all the features already discussed about tutorial learning.

The script, the product of design, is the key to this activity. It is a full visual representation of how the eventual program behaves for all students. It shows the messages the students will receive the analysis of the input, what information is stored, and how this information is used in the program. Initially the scripts were on paper, but about 10 years ago Bertrand Ibrahim at the University of Geneva created an on-line script editor. Much of the code could be written by the computer from the stored script. Assistance for programmers creating the parts of the script not programmed by the computer is offered by the script editor. Corrections for later generations can also be made in the script. This editor is described further in Tutorial Distance Learning (Bork & Gunnarsdottir, 2001). Recent efforts by Rika Yoshii (Yoshii, Wu, & Miao, 2001) at the California State University, San Marcos, interpret the script as the program runs.

Evaluation and improvement are critical activities in development, planned by professional evaluators. We recommend several stages, with extensive use with a wide variety of students. Data is mostly stored by the computer as students use the program.

COSTS FOR TUTORIAL LEARNING

The cost of learning needs careful consideration. Learning must be affordable for all, if it is to be available for everyone. Unfortunately, current estimates of cost are often inaccurate, not looking at all the factors contributing to costs. The cost for an hour of student learning is the most important figure. This issue is more completely discussed in chapter 12 of Tutorial Distance Learning (Bork & Gunnarsdottir, 2001). Some of the factors involved are not fully understood at the moment; they depend on more experience with such adaptive units.

Many factors are involved in determining costs, including the cost of development, the cost of delivery, profit (if any), and the cost of the management structure. They are briefly considered in this section.

1. Development costs

   In the post-Sputnik development mentioned at the beginning of this paper, a course cost millions of dollars. A course at the United Kingdom Open University costs a similar sum to develop. Most recent development in the United States, such as the Web-based university courses, costs much less, but one can raise serious questions about quality of these passive courses. The computer-based learning literature is full of useless statements that it takes 300 or so hours of time to produce 1 hour of student time, again a low figure for quality material, and not a reasonable way to approach the costs of development.

   Development is not the whole ball of wax, so considering this alone in computing costs is very misleading. The United Kingdom Open University has long demonstrated that expensive development of quality material can lead to low costs per student.

2. Delivery costs

   Conventional university courses have little development costs, but high delivery costs, because of the salaries of professors and needed equipment. Costs increase as numbers of students increase. Self-study such as reading a book has a low delivery cost.

Delivery costs include both the cost of the equipment needed, and the cost of accessing the learning units. Current computers are adequate, even over-kill, for delivering tutorial learning. Eventually we should be able to build such a computer, not a general purpose computer, but one built particularly for highly adaptive learning units, for under $100. It would have a much simpler operating system than computers now. Solar powered units, now practical, would be needed in places without reliable electricity.

As mentioned, access now could be either through CD ROM or the Internet, whichever is cheaper and easier to access. Identical materials would be available either way. Current bandwidth is adequate, as the interactions would take place in the local computer. Eventually wireless access is likely, perhaps on a special network only for learning.

An interesting factor in delivery costs is the number of students who can learn with the approach used. With some kinds of learning, delivery costs increase with the number of students, but another possibility is that they decline, per student.

3. Management costs

In a conventional school these include all the administrators, often a considerable number, and all the record keeping. With computer-based distance learning, the computer maintains all the records and does the administrative work at a low cost per student. But we will still need groups to maintain the learning units and to plan for the development of new units.

Tutorial distance learning can reach large numbers of students, with low costs per student. With large numbers, expensive development is coupled with low delivery costs.

BACK TO TEACHER TRAINING

After this interlude to discuss tutorial computer-based learning, we return to the problems with teacher training. There are two ways out of the dilemma presented by to typical failure of teacher training: computer-based learning for teachers, and computer-based learning for students.

We should try both of these approaches. Probably, both will be needed, at least in the immediate future.

Careful experiments in both directions are desirable before large-scale development takes place. These should include extensive longitudinal studies on the results. Many students of all types of background should be considered.

We have great possibilities for improving learning for everyone, going far beyond the problem of training teachers.

> This new version of education emphasizes a holistic interdisciplinary approach to developing the knowledge and skills needed for a sustainable future, as well as the necessary changes in values, behaviour, and lifestyles. This vision requires us to re-orient educational systems, policies, and practices in order to empower everyone – women and men, young and old – to make decisions and to act in ways that are culturally appropriate and locally relevant in order to address the problems threatening our common future.
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> Koichiro Matsuura, UNESCO Director-General, World Summit on Sustainable Development, South Africa, September 2002.

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