

COMPUTERS AND EDUCATION IN THE 21ST CENTURY

by Patrick Suppes

Historical Perspectives

I begin with a historical perspective on the great educational innovations of the past. I identify five major technological innovations that are comparable to the current computer revolution.

Written records. The first is the introduction of written records for teaching purposes in ancient times. We do not know exactly when the use of written records for instructional purposes began, but we do have, as early as Plato's Dialogues written in the 5th century B.C., sophisticated objections to the use of written records.

Today no one would doubt the value of written material in education, but there were very strong and cogent objections to this very earliest innovation in education. The objections were these: a written record is very impersonal; it is very uniform; it does not adapt to the individual student; it does not establish rapport with the student. In other words, Socrates and the ancient Sophists, the tutors of students in ancient Athens, objected to introducing written records and destroying the essential personal relation between student and tutor.

It has become a familiar story in our own time that a technological innovation has side effects that are not always uniformly beneficial. It is important to recognize that this is not a new aspect of innovation but has been with us from the beginning.

Libraries. The second innovation was the founding of libraries in the ancient world, the most important example being the famous Alexandrian Library that was established around 300 B.C. Because of certain democratic traditions and the preeminence of the creative work in philosophy and poetry, it is easy to think of Athens as the intellectual center of the Hellenic world. In fact, that center was really Alexandria. From about 250 B.C. to A.D. 400, not only was Alexandria the

most important center of mathematics and astronomy in the ancient world — it was also a major center of literature, especially because of the collection in the Alexandrian Library. The first real beginnings of critical scholarship in the western world of literature, the editing of texts, the analysis of style, the drawing-up of bibliographies took place in the Alexandrian Library. This revolution in education consisted not simply of having in one place a large number of papyrus manuscripts but in the organization of large bodies of learning. Scholars from all over the western world came to Alexandria to study and to talk to others.

Libraries of a substantial nature were to be found in other major cities of the ancient Mediterranean world, and in China, India, and Korea.

Printing. The third innovation of great historical importance in education was the move from written records to printed books. In the western world we identify the beginning date of this innovation with the printing of the Gutenberg Bible in 1452. It is important to recognize, however, that there was extensive use of block printing in Korea and China three or four hundred years earlier. Nearly half a millennium later, it is difficult to have a vivid sense of how important the innovation of printing turned out to be. In the ancient world of the Mediterranean there were only a few major libraries, a number so small that they could be counted on the fingers of one hand. By 100 B.C. the Alexandrian Library had few competitors. The reason is obvious. It was impossible to have large numbers of copies of manuscripts reproduced when all copying had to be done tediously by hand. The introduction of printing in the 15th century produced a radical innovation — indeed a revolution — in the distribution of intellectual and educational materials. By the middle of the 16th

century, not only European institutions but wealthy families as well had libraries of serious proportions.

Once again, however, there were definite technological side effects that were not uniformly beneficial. Those who know the art and the beauty of the medieval manuscripts that preceded the introduction of printing can appreciate that mass printing was regarded by some as a degradation of the state of reproduction.

It is also important to have a sense of how slow the impact of a technological innovation can sometimes be. It was not until the end of the 18th century that books were used extensively for teaching in schools. In arithmetic, for example, most teachers continued to use oral methods throughout the 19th century, and it was not until almost the beginning of the present century that appropriate elementary textbooks in mathematics were available. Fortunately, the scale of dissemination in the modern world is of an entirely different order from what it was in the past. Perhaps my favorite example is the estimate that it took over five years for the news of Julius Caesar's assassination to reach the farthest corners of the Roman Empire. Today such an event would be known throughout the world in a matter of minutes.

With regard to the pace at which books have been introduced into education, it would be a mistake to think that there was something peculiar about the use of methods of recitation in the elementary school until late in the 19th century; stories of a comparable sort also hold at the university level. According to at least one account, the last professor at the University of Cambridge in England who insisted on following the recitative tradition that dates back to the Middle Ages was C.D. Broad. As late as the 1940s, he dictated and then repeated each sentence so that students would have adequate time to write each sentence exactly as dictated. I cannot imagine contemporary university students tolerating such methods.

Mass schooling. The fourth innovation, and again one that we now accept as a complete and natural part of our society, is

mass schooling. We have a tendency in talking about our society to put schools and families into the same category of major institutions. But it is extremely important to recognize the great psychological difference between the status of the family and the status of schools. Families are really deep into our blood and our culture. The evidence of families in one form or another as being the most important cultural unit goes back thousands of years. Schools are not at all comparable; they are, we might say, very much Johnny-come-lately to our culture. Over a hundred years ago, in 1870 for example, only two percent of young people graduated from high school in the United States. A hundred years before that, only a very small percentage even finished third or fourth grade. I cannot give you an exact percentage because our record-keeping, that is, our social statistics, are not much more than a hundred years old, and we have no serious idea of how many students were actually in school two hundred years ago, except that we do know that the number was quite small.

Even as short a period as fifty years ago, in most of the world less than one percent of the population completed secondary school. During the recent upheavals connected with the "cultural revolution" in China, the elementary schools, not to speak of colleges and secondary schools, were closed for several years. In our society as we now think of it, it is unthinkable to contemplate closing the elementary schools for such a period of time. From a Chinese historical perspective, however, it was not such an important matter, for Chinese culture extends back continuously several thousand years, and there is in that cultural tradition no salient place for mass schooling.

In many developing countries of the world today the best that can be hoped is that the majority of the young people will be given four years of elementary school. Until population growth is brought in check, it will take all available resources to achieve this much. The position of America as a world leader in education is sometimes not

adequately recognized. In fact, our leadership in creating a society with mass education is one of the most important aspects of American influence in the world.

As recently as the latter part of the 19th century, the British philosopher, John Stuart Mill, despaired of democracy's ever really working anywhere in the world for one reason — it was simply not possible to educate the majority of the population. In his view, it was not possible to have a significant percentage of the population able to read and do arithmetic. The revolution in mass schooling is one of the most striking phenomena of the 20th century.

Testing. The fifth educational innovation is testing, which is in many ways older than the concept of mass schooling. The great tradition of testing was first established in China; testing there began in the 5th century A.D. and became firmly entrenched by the 12th century A.D. There is a continuous history from the 12th century to the end of the 19th century in the use of tests for the selection of mandarins — the civil servants who ran the imperial government of China. The civil service positions held by mandarins were regarded as the elite social positions in the society.

The importance of these tests in Chinese society is well attested to by the literature of various periods. If one examines, for example, the literature of the 15th or 16th century, one is impressed by the concern expressed for performance on tests. A variety of literary tales focused on the question of whether sons would successfully complete the tests and what this would mean for the family. (As you might expect, in those days women had no place in the management of the society and no place as applicants for civil service positions.) The procedures of selection were as rigorous as those found in a contemporary medical school or a graduate school of business in the United States. In many periods, fewer than two percent of those who began the tests (which were arranged in a complicated hierarchy) successfully completed the sequence and were put on the list of eligible mandarins.

Although testing has a history that goes back hundreds of years, in many ways it is proper to regard it as a 20th-century innovation, because it was only in this century that the scientific and technical study of tests began. It is only in this century that there has been a serious effort to understand and to define what constitutes a good test for a given aptitude, a given achievement, or a given skill.

The five innovations that I have discussed — written records, libraries, printed books, schools and tests — are the very fabric of our educational system today. It is almost unthinkable to contemplate a modern educational system without each of these innovations playing an important part.

Of these five technologies, the impact of none has been adequately forecast at the time of introduction. Of course, a few individuals foresaw some of the consequences and had something to say about those consequences, but certainly the details had not been accurately foreseen. I am certain that the same thing will be true of technologies now developing for use in the future, and so I do not want to appear confident that what I say is a correct scenario for the next century.

What Computers Offer

I am sure that what I have to say about what computers will offer to education in the 21st century will also fall in the category of inaccurate prognostication. There is not much I see that I can do about my predictions. The field is changing too much. The shape of the technology and its applications is as yet too impermanent. There are also important matters of time scale in any attempt to make predictions. It is very different to talk about computers in 2001 as opposed to a hundred years from now in 2084. I shall reach for the hundred-year prediction and leave it to you to interpolate for the dates in between. In a certain sense, this is an easy route for the particular case of computers because it is reasonable to assume that any particular technical problem that we are centered on today will have disappeared

or have been so radically transformed by a hundred years from now that there is little use in trying to foresee the exact configuration of solutions.

The classic argument for computers' having a central role in education a hundred years from now is the same as the classic argument for hiring the services of a tutor in ancient Athens. What is that argument? The adaptation of instruction to the idiosyncratic characteristics of a single pupil and the interaction of that pupil with his tutor.

In addition to this argument for individualism, I shall pursue the expected argument about information accessibility and also one about the augmentation of technical skills. These are in essence very curriculum-oriented topics. Later I shall move to the broader institutional setting of education and the way in which I think it will be transformed.

Individualization. It is both vivid and accurate to think of the model of a tutor in ancient Athens, but it is not sufficiently conceptual and abstract in characterization. What are the arguments for individualization in instruction? First, and above all, there is immediate attention to individual responses. Second, there is correction of these responses and information conveyed about their character, especially when the answers given are judged incorrect. Third, the pace of instruction is adapted in delicate and subtle ways to the pace of learning of the individual student. Relatively simple computer systems can give us these three features, together with the virtue of active participation by the student as a learner as opposed to being a passive listener.

About a hundred years from now we expect something from computers that is more like what we expect from sophisticated tutors. First of all, and of greatest importance in the Greek conception of instruction, is dialogue between tutor and student. Plato's dialogues are not really good models of instruction but are meant to serve a different purpose. Socrates is always talking, and others are giving relatively short answers. Good dialogue of an instructional sort should

feature much more talking by the student and listening by the tutor. Now all of us know that listening by computers is in a very undeveloped state, but there is no reason to think that the present formidable technical problems of constructing really good listening computers will not be solved in the next hundred years. Good instructional computers should, above all, be good listeners, but they also need to be good talkers, for the young learn how to talk by listening to talk.

To construct computer-instructional programs that can conduct intelligent dialogue with students, the problem is not in any central way the technical one of solving the problem of understanding spoken English or some other natural language. The real problem is understanding how to conduct a dialogue. All of us are used to conversation, and some of us are capable of really good instructional conversation as well. But we do it by the seat of our pants, so to speak — we don't really understand how we do it. The theory of dialogue is as yet hopelessly undeveloped. It certainly must be high on the agenda of future instructional theory. No matter. Very likely we will have good dialogue instruction by computer in many areas without fully understanding how the programs have been built. There are many ways that such matters can be approached. Good learning facilities, for example, would permit us to teach programs how to talk or, more specifically, how to conduct good dialogues on given subject matters, and we would not necessarily need to know exactly how the computer learned to conduct such dialogues. In any case, I have great confidence that in a hundred years we shall have computers that do an excellent job of giving tutorial instruction in a wide variety of subjects from mathematics to music. It is important to emphasize that good interactive instruction of the kind we expect from a good tutor can in other respects be rather limited. One does not have to be a marvel of psychological understanding, wit, and rhetorical elegance to do a first-class job of teaching another person physical optics, organic chemistry, or the classical economic theory of the

marketplace.

But our ambitions for good computer instruction will not stop with the phenomenological features of a good tutor — we want more. We want good instructional programs to also have a good cognitive model of the student and his learning problems. Now intuitively, a good tutor has a sense of what is going on in the head of the student, but ordinarily a good tutor does not have an explicit cognitive theory of how the student is solving problems and why he is getting stuck in his problem-solving efforts. Some aspects of the process seem extraordinarily mysterious, but there is no reason to think that we cannot make headway on many important features of such a cognitive model, even if there are depths that a hundred years from now we will still not have plumbed. Such models of thinking and problem solving are like models of talking. There is no reason to think we will be able to reach any serious and final degree of completeness, but there is also no reason to be overly pessimistic. There is much that can be done, and we should expect and demand in a century of effort some rather surprising results.

Finally, I mention something else that a good tutor is able to handle well, and that is activating the sources of motivation in a student, which make the student want to learn in a continuing and serious fashion. We do not know all that we need to know about motivation now, and again there is no reason to think that we will reach the end of the mysteries in a hundred years. But there is also reason to think we will be able to understand matters much better than we do now. In fact, I often like to draw the parallel to physical and musical skills. Even though we do not theoretically understand students' motivation in learning physical skills or in the performance of music, in many cases we do seem to be much better at providing proper motivation to make a serious effort. We should, in the next hundred years, at least hope that our understanding of how to motivate the exercise of cognitive skills will begin to catch up with our practical methods for motivating the development of physical

and musical skills.

There is an important point to make about this rather abstract discussion of dialogue between tutor and student, cognitive models and motivation. We can very well put this analysis in the framework of general problems of education, but I want to emphasize that I see particular headway being made on these important problems just because of the availability of sophisticated computers. We shall have both means and also the challenge to develop instructional techniques far beyond anything that we have done thus far, just because of what will be available to us as rich resources for the best possible sort of individualization.

Accessibility of information. The transformation of learning that will take place due to the much greater accessibility of information will be a greater transformation than that which took place with the creation of the Alexandrian library more than 2,000 years ago. Scholars of the ancient world properly stood in awe of the resources at Alexandria. The kinds of resources that were brought together there in one place will be available in every nook and cranny of the land. This availability of information by electronic means will have its greatest impact, in my judgment, in the potential for the decentralization of our society, a topic that I shall speak about at greater length in a few moments.

Augmented technical skills. We are all familiar with the kinds of problems that can be tackled with current computers, but that were simply out of reach even thirty or forty years ago. These problems range from massive computations about the weather to linear models that are applied to every sort of problem from medicine to economics. Students in undergraduate classes now perform in a routine fashion numerical calculations that were unheard of as little as thirty or forty years ago and that were impossible for anyone fifty or sixty years ago. Such numerical power will continue to increase, but what I think is at least as important is that the number-crunching computers of today will be joined by the symbol-crunching computers of

tomorrow. We shall expect symbolic analysis at our fingertips in every direction, whether it be applied to the structure of DNA, a complicated mathematical equation that has to be transformed, or a mathematical proof that needs completion of its combinatorial parts. We shall, I predict, become, both in instruction and research, as dependent on symbol crunchers as we now are in many parts of science on number crunchers. The effect of these two in combination will be to augment our technical skills and the level we expect of sophisticated instruction in technical skills far beyond anything that we have seen up to the present. There is some reason to think that the next levels of scientific development in many different disciplines will necessarily involve a level of complexity beyond what we have seen in the past. A thesis that science will keep unifying and keep simplifying is, in my judgment, much more a romantic hope than a conclusion supported by the actual development of science over the past fifty years. If my view is at all close to the truth, the problems of instruction will become ever more difficult. We will need every resource we can have to augment our technical skills. Computers will be far and away the most important means for doing so.

Changes in the Institutional Framework of Education

Even harder than forecasting the developments in computers for instruction is forecasting how the availability of such radically new information technology will change the institutional framework of education at all levels. As I said earlier, my objective is to give a forecast for 2084. There is no doubt that much of what I have to say will be regarded at that time as a naive fantasy, but I shall push ahead, firm in the conviction that my errors of prediction will not be much worse than anyone else's. I have organized my thoughts about the distant future into three main parts: first, the elementary and secondary schools, or what will be their equivalent; second, post-secondary education divided into college and continuing education;

and, third, future education in the home.

Elementary schools. Just as the family has great stability, so do elementary schools, being the closest to the family, also have the greatest stability of any of our educational institutions. They are the ones that are the most widespread in the world and that will, I think, remain the closest to their current appearance a hundred years from now. I like to claim that the greatest agent for uniform socialization in the world is the first-grade classroom. They are remarkably the same everywhere in the world. A teacher is in charge of twenty to forty-five youngsters ranging in age from five to eight years, and the curriculum is remarkably similar, the greatest emphasis being on reading and the next greatest emphasis on arithmetic, with the beginning skills of writing a close competitor.

I see two major ways in which elementary schools may well change by 2084. First, there will be a tendency toward decentralization and teaching in smaller groups. Even when the schools have several hundred children as they do now, the ratio of students to teachers should decrease. It is one of the ironies of American education that the student-teacher ratio is greater in the elementary school than in the secondary school in just about every school system in North America, but if any conclusion can be drawn from a wide variety of research on this question, it is that the smaller class sizes should be for the younger children, not the older ones. This insight will, I think, gradually come to have some force in the span of a hundred years. There is no reason that we should not have a student-teacher ratio of ten to one, rather than the current ratio in North America of somewhat larger than twenty to one. A second aspect that will help this ratio is the forecast that the birth rate will continue to decline, and children will be seen as even more important and deserving of even more attention than is the case today.

The second main change will be the vast array of information technology available to the teacher. Much of the routine instruction in reading, writing, and

arithmetic can first be given by computer. The teacher can be there to keep a close eye on the sources of difficulty, to reassure and help the child that is having momentary problems of an emotional kind as well as of a cognitive sort, and to engage in that free flow of talk between adult and child that is so important for the sophisticated development of children. In other words, the purpose of the computer technology will be to relieve the teacher of onerous routine and to free him or her for more focused attention to individual youngsters. Above all, I emphasize, there should be no sense of competition between the technology and the teacher, just as there is no competition between books and teaching staff. The computer technology is there to help, not to hinder the education of the child.

I am not spending as much time on curriculum in this lecture because of the range of topics I am covering, but I do want to emphasize that the introduction of computer technology in the elementary school will permit an attention to the individual history of learning and of learning difficulties of each child that is simply not possible today. The teacher will be given resources and immediate analyses to help in working with individual children's difficulties. But it is not just a case of helping with difficulties. The technology will also be there to make rapid progress possible for those students who feel squelched by the uniform regime of the group moving together through a given curriculum. The student who can go quickly in one subject, be it reading or mathematics, will be permitted to forge ahead; the technology will be there to provide all the tools for forging ahead, and the teacher will be trained to encourage the forward march. We know from individual testimony how much certain gifted individuals have learned by the age of twelve or so, mainly because of the extraordinary personal environment in which they fortunately happened to be placed. It should be an item high on the agenda of education for the 21st century to provide that kind of rich environment for every gifted student. Let us remember also that

being gifted does not mean being gifted in every respect. For almost all students, as John Dewey used to emphasize many years ago, there will be areas in which their gifts shine forth, and they should be encouraged to develop them as rapidly and as thoroughly as possible. Technology above all can help do this.

Secondary schools. Here my theme is that the technology should be used to decentralize the secondary schools that are in most of the world too large, too bureaucratic, and socially too complicated. The move from the little red school house of the 19th century to the comprehensive high school of the 20th century is one of the great triumphs of mass schooling and one of the educational achievements that will have a permanent place in the history of education, but it is time now to move on to new opportunities and better things. We are in a position to return to the analogue of the little red school house because we can bring to the decentralized school for teaching fifty, a hundred, or two hundred secondary-school students all of the educational resources that have been the glory of the comprehensive high school. It is important to emphasize my claim. The only real reason not to decentralize the large secondary schools of today is the problem of providing sufficient individualization of instruction, in this case, individualization of subject matter, so that one student can study calculus, another photography, and another auto mechanics. I am not trying to say what the diversity will be. We currently have a tendency to once again emphasize a concentration on basic academic subjects in high school, but whether that will be the case in a hundred years is difficult to say. What we will have is the technical capacity to decentralize, to bring to small teaching units, an degree of diversity desired in instruction. We can have stored in that secondary school for a hundred students library resources equal to the current Library of Congress, the largest library in the world. The problem will not be having the resources; the problem will be in understanding how to use them. What we will need is sophisticated instructional program

to guide the students and to help them learn the great range of possible subjects that may engage them.

As you can see, I feel strongly about the wisdom of decentralizing secondary schools, but apart from my strong psychological feelings about this move, there are also strong economic arguments. A hundred years from now, it will be even more evident than it is today that it is much more economical to move information than people. Schools will be close to where adolescents are living. Teachers will be like tutors, but not like the tutors in ancient Athens in the sense that they will not be carrying the full load of instruction. Teachers in secondary schools will be counselors and trouble shooters, not just counselors about future careers or emotional problems, but cognitive counselors, able to help when a student has not found the right mix or the right approach to instruction in the wealth of technological offerings. The demands on teachers will be greater than they are now. They will need to be more professional and more deeply trained, and they should be paid much better than they are now. The expert teachers I see as needed in the technological setting of the secondary school in 2084 must be technically expert and intellectually sophisticated. They should be compensated accordingly.

Colleges. Some of you who may accept my prediction about the rapidly decreasing size of secondary schools may balk at the idea of colleges going through a similar reduction. After all, the story of higher education in the second half of the 20th century is one of increasing concentration of students on campuses. I think, however, that we can already see the signs of decentralization in local community colleges near where I live. It is now the practice to have off-campus centers to which students may go for courses. In fact, for many courses, it is only necessary to appear on the campus twice, once to register and once to take an examination. A hundred years from now a college of several thousand students may be the largest to be found anywhere. This will happen only if we see a degree of specialization that we do not now

have in colleges. So I am less certain about my prediction here because there is a certain importance to having numbers of students commingling who are engaged in research at the level of graduate study. Highly sophisticated laboratories will not be easily decentralized, and so it may not be possible to decentralize college campuses as much as secondary schools. I do emphasize, however, that I could be quite wrong about this, for if we look around at the current situation, as I have already indicated there is in North America a stronger current tendency to decentralize community-colleges than high schools.

I want to say something about the college curriculum apart from any questions of decentralization. One of the technologically most efficient ways to teach young adults is to have them listen to a stand-up lecturer talking to two or three hundred of them at a time. I do not think we should abolish this classical form of lecturing, but I do think it is an inefficient form of learning from the student's standpoint. It is too passive, and it is too rigid in its pacing to accommodate individual differences in learning. The reason I think it should not be abolished is that there are matters of style and viewpoint that are not easily conveyed in other ways, although I do not want to emphasize this point too much. In our modern age of television, we have a sense of intimacy and closeness of perception of speakers that is simply not possible in a large audience but that is easily replicated in teaching by means of video technology. Thus, even what I say about large lectures may be wrong, but I am conservative enough to see some value in the diversity of approaches and the retention of this classical form.

I do want to emphasize that for the past ten years I have not given a lecture course myself. I teach my undergraduate courses by computer or videotape. My personal teaching is entirely confined to seminars, of which I teach a great variety. This is the model I would urge for 2084. The standard preparation of students in terms of skills or knowledge should be done in sophisticated

technological setting, mainly using computers and associated video devices. With appropriate preparation, students should then enter seminars ready for discussion and talk, and I emphasize, above all, talk on their part. So what I am describing for college education represents a transformation of current teaching methods, one that will be agreed to by people of differing attitudes toward the promise of technology. However, without the technology, it will not be possible, in practice, to use a skilled academic faculty entirely for seminars. It would be too expensive to cover the bulk of teaching in this way. I could even give some numbers from my own experience as to what it is reasonable to expect from college faculty, but it would be too outrageously specific to put down these numbers as a forecast for a hundred years from now.

Continuing education. Continuing education is already following the pattern I have mentioned of the community colleges, namely, off-campus centers and also home-centered learning. The percentage of the adult population in some community-college districts in California that is involved in continuing education is staggering. The number is as much as forty percent in some cases. I see no reason to think that continuing education will decrease, and many reasons to believe that it will continue to increase. A hundred years from now, continuing education of an organized systematic kind may very well be the norm for all adults until very late in life. How is this vast panoply of continuing education going to be arranged? Well, first of all, it would be a mistake to have some monolithic single model of how it will take place. Such a model does not describe the enterprise today and certainly will not a hundred years from now. On the other hand, there are certain tendencies, and certain arguments as to why those tendencies will increase, why things should be stated. Again, the most important tendency I see is one of decentralization. That tendency will continue. The second tendency will be to use information technology to make continuing education much

more independent of the immediate presence of a human teacher than is now the case. This increasingly sophisticated use of the technology will increase the possibilities of decentralization. In fact, as I want now to discuss, decentralization will be to that ultimate point of decentralization, the individual's home.

The home. The prospects that are the most dazzling and intriguing of all concern the return of education to the home. Will this happen in a hundred years? I think it will, and of course, I could be dead wrong. But I think there are many reasons why much of education should return to the home, and that return should also be associated with the return of work to the home. Let me spend a few moments on a forecast of the general place of the home as the place of work a hundred years from now. As late as 1920, somewhat over half of the population of the United States was still rural. The countryside of the United States and of Canada as well is now depopulated. In the United States, less than four percent of the population is engaged in agriculture. Agriculture is the great technological success story of the 20th century in North America and is a highly capital-intensive industry. Farm labor is almost nonexistent beyond the family unit. Individual families sit in lonely serenity on several hundred acres, with the nearest neighbor being at least half a mile away. Not everybody likes isolation of this kind. It will be an opportunity and a choice in 2084 in a way that now is not. As has been remarked upon by a vast number of futurists predicting what the 21st century will be like, we have already entered the post-industrial era. This is the age of information, and the handling of information can be conducted as well from the home as from the office. The choice will be before us. A hundred years from now, it is possible that the family will seem much stronger and more closely knit than it is today. Everyone has been predicting the end of the family for the past 150 years. I shall be boldly optimistic and predict its renewal. I do not think that individuals will work totally in isolation at home, but they will have a

pattern of work that is much more flexible and interesting than the pattern of going to an office forty hours a week so customary today. An individual could work at home three or four days a week and perhaps go to the office one or two days a week. The parents of a family of one or two children could always arrange for one of them to be home, and the children could be educated as much as the parents liked at home. I also do not think the education of the young will move back to the home to become as it was until sometime in the 19th century, or for most of the world until the 20th century.

I can envision a pattern something like the following for a family of two children between the ages of five and fifteen. The father goes to the office only on Mondays, and the mother only on Wednesdays. The younger child, who is in elementary school, goes to school in the morning and then works another couple of hours a day, using appropriate computer technology, under the general supervision of the parents. The older child also spends mornings at school, perhaps for a slightly longer period than the younger child, but the older child also spends the afternoons at home, continuing the educational program under the general supervision of the parents and also possibly helping the younger child. There is in the entire household a learning environment. The mother and father are involved in complicated programs of continuing education in their own areas of specialization. The children are learning a diverse variety of things and are very able and sophisticated about looking up a bewildering array of information in the enormous sources available to them in the hundred giga bytes of storage available to them in optical form at home.

There is one further point I want to make about this return to the home. Some of the mothers who have recently moved from home to workplace may not like the idea of the drudgery they see returning to them as the most responsible agents for management of the household. Here too I want to be optimistic. I cannot think of anything that will sell comparable to the sale we shall see

of smart robots, once they are available for household work. We certainly do not have them now. We will not have really good ones in twenty years, but with the market impetus to develop such a product, once a few outstanding technical problems are solved, the push to develop really excellent robots for household work will be unbelievably strong. Surely in a hundred years we will all have superb, highly reliable servants of the new electronic kind. Looking back from the perspective of 2084, it will be a point of conversation that it was only in the 20th century that educated, affluent people did not have servants. Through the 19th century these servants were other humans, and the relationships of subservience were not always the most desirable. But in the 21st century the right kind of servants were introduced, the electronic kind whose only *raison d'être* is that of service.

Conceptual Questions and Problems

I close by mentioning some of the general guidelines and issues that certainly could go either way in the developments of the next hundred years.

Privacy versus sociability. I have emphasized throughout this lecture the enormous potential for decentralization in our society a hundred years from now, especially as it affects education. I do not want to leave you with the impression that I think all education should be private and that learning is always best engaged in a private setting. There are many aspects of group learning that should be a part of everyone's experience. Social instincts are a natural part of human psychology. What we are faced with in the future is the possibility of new mixes of privacy and socialization. Much of the world's population until the last couple of hundred years lived in small social groups in rural settings. It is this ancient social possibility that will be technically and economically feasible in the future once again. Many people, I predict, will want to return to it. Those who prefer a crowded metropolitan environment, as did many people in the days of ancient Babylon or Alexandria, can

continue to live in urban circumstances, but even then there will be varying degrees of privacy possible. What the norm will be is hard to say from this distant point.

Commonality versus diversity. One of the great problems for education a hundred years from now, with all the rich information technology available, will be the mix of common and unique elements in the education of each individual. By this I mean, how much will the education of the young be devoted to a core curriculum and how much will be a matter of diverse choice? My crystal ball is cloudy on this point, but I predict greater diversity, if only because of the exponential growth of knowledge we can anticipate for another hundred years.

Freedom versus control. The final issue

to be mentioned is the place of individuality and human freedom in the kind of modern society we can anticipate for 2084. There are Luddites now, and I am sure there will be Luddites then that preach the danger of men becoming slaves of machines. This is an extreme and romantic way of putting what can be regarded as a real danger, namely, the use of high technology by one group of men to enslave another. These dangers and many others lie before us in the next hundred years, but we have also the hope and the promise of a society that is intellectually sophisticated and materially affluent beyond any that has ever been seen before. The use of computers can, through the elimination of drudgery and an effective emphasis on individuality, be a key element in creating a better world than we have ever known before.