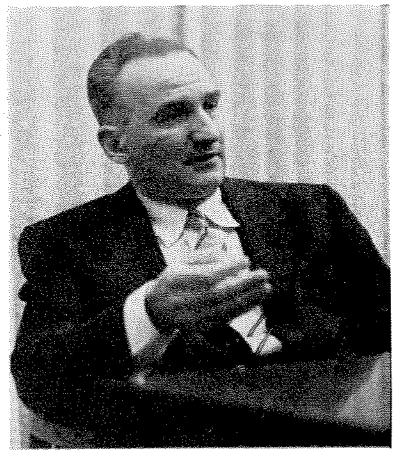

A NEW TECHNIQUE OF EDUCATION

by SIMON RAMO

A noted scientist proposes some radical changes in our educational system to bring it in line with our increasingly technical world

WE ARE IN RAPID transition today to a new world which threatens to be dominated by technological advance. In that new world, (1) man will have learned so much about nature's store of energy and its release that he will have the ability to virtually destroy civilization; (2) production, communications, and transportation will all be "automatic"—these operations of man's material world will have become so vast and complex that they will have to proceed with a minimum of participation by man, his muscles, brains, and senses; and (3) man will conquer space.

There seems little question that these three factors will have dominant effects in the coming decades. The effects are already being felt. (There is even a serious note in the facetious thought that any man who has the courage to stand up and claim that the replacement of man's brains will not have a very important effect on society takes the risk of having his brains among the first to be replaced.)

By hindsight, what is happening would appear to have been entirely predictable centuries ago. We might consider all of man's history until now arbitrarily broken up into two periods, the second of which is now in transition to the new and third one.

In the first period, which might be called the "pre-science" era, man was not consciously employing science to alter his society. Of course he was aware of the world about him, and he sought to adapt himself to nature's laws. But when he objectively began to develop organized ways of thought and experimentation to further his knowledge of nature, then he entered the era of the "discovery of science and its utilization." One step in this second period is the so-called industrial revolution.

In this second era, now coming to an end, man learned to communicate and navigate, to create and harness sources of power well beyond his own muscles, all with the natural result of increased production and fast transportation. In such an era, man would be expected to learn gradually more and more about matter and energy, so as to make possible the release of larger and larger amounts, to the eventual point where he could quickly destroy civilization. He would be expected to so increase and speed up production, transportation, and communications as to tie the entire globe together in an enormous network of automatic machinery, cables, and moving vehicles. In time he would have such potentialities in the control and generation of energy, and in communications and transportation, as to make possible intercontinental ballistic missiles, space satellites, and rockets to the

"A New Technique of Education" has been adapted from a talk given before the California Business Education Association by Simon Ramo, research associate in electrical engineering at Caltech, and executive vice president of The Ramo-Wooldridge Corporation.

moon. So, finally, he would spread out from the surface of the earth to all the space surrounding it.

And the transition is happening just this way to the new technical age. What makes the present period singular is that now, for the first time, a sharp coincidence between the needs and the state of the art exists. The requirements for the new society, the pressure, and the strength of resources to bring it about, now match a sufficiently deep understanding of the laws of nature to make these big steps practical.

Considering the needs

Consider first the needs. As one example, note that we are already at the point in air transportation where we badly need a major entry of automatic techniques in the over-all system for airline navigation and traffic control. Today we are alarmed about occasional accidents. But it will hardly take very much increase in the number of cities originating plane flights, or in the amount of air freight to be handled, or in the spectrum of speeds from the very low-speed helicopters to the high-speed jets, or in the demand for reliable operations in all-weather conditions, before we approach near-chaos at the airports and intolerable dangers in the air lanes.

Similarly, the military situation demands the extension, and often the replacement, of man's brains and senses by automatic gadgetry. The guided missile is taking over in many areas from manned airplanes. Getting up into the skies swiftly in response to detection of enemy bombardment vehicles, finding the location and the expected future path of such enemy vehicles, making the decisions as to what path should be chosen to effect an interception—these functions, to be accomplished with tremendous rapidity for fast vehicles in all weather, and involving a great deal of mathematical complexity in the decisions, are well beyond the pilot's eyes, ears, and brain.

Business and industry — whether it be department stores, insurance companies, banks, railroads, or ordinary factories—have become so large and complex that the sound containment of their operations from an organization standpoint becomes more and more impossible without the use of automatic techniques.

Now the status of science is such that, without a single new discovery—without even one more new law being discovered by an Einstein concerning the nature of the universe or the secrets of the nucleus—we can set out to design mechanical and electronic systems that will take over, and do better, many of the things we now do with our brains and senses.

The coming crisis in education

This rapid and potentially dislocating scientific advance can be expected to heighten and worsen the coming crisis in education. Already, the increasingly technical world uses more scientists and engineers, yet the very industrial development that is part of the growing technical society takes the engineers and scientists away from the university and high school facilities, and the fast world in which we live makes the long study of science seem unattractive to the youngsters. The technical society is complex, rapid, and increasingly dangerous. We can blow up the whole world, yet such a premium is put on the use of our human and physical resources for everything but education that it seems that the new technical society is going to be accompanied by a weakened ability to keep pace education-wise.

Now, if the world were in transition to something different on a very, very slow scale, we could argue that these factors would take care of themselves. Supply and demand would then presumably set to work to make the teaching profession pay off better. Further, the new technical society would be expected to cease to develop rapidly if there were not enough engineers and scientists to make possible that development. So the pace would have to adjust itself to one that would allow all the factors to settle into their respective permanent relative magnitudes.

Looking ahead

But we are moving much too rapidly for that, and our technical growth is paralleled by social maladjustments still left over from previous eras. The adjustments, instead of being slow and stabilizing, could be chaotic. Obviously, something new is needed. Education should be at the head of the list for priority attention. Our hope for attaining any kind of stability in the highly technical world ahead must rest on the ability to look ahead, understand the world and adjust to it. We must reject such solutions as that we do indeed blow ourselves up; and we cannot accept something approaching a robot-controlled world that consists largely of ignorant and uneducated masses who are slaves to a few individuals who push all the buttons on the machines.

A new technique of education

I should like to propose that these very technological advances, about which we normally speak when we talk about the new technical society, must include advances in the field of education, and it is part of the obligation of those of us who are engaged in the engineering side of modern science somehow to apply ourselves to help the process of education. What is needed is a technique of education which is in keeping with the world ahead.

Picture this new technical society—in which the entire airline system, from reservations to blind landing and take-off, is done almost automatically, with the pilot going along only for the ride; in which money is used only in the country communities, and when we buy something in a store we simply put our thumbs up against a little window, our fingerpints are automatically scanned against our balance, and the proper change is made in the respective accounts of the customer and the store—and ask: what will a high school look like at that time?

We have a choice here of two ways to discuss this. We could take it in very gradual steps, starting with the popular suggestion of greater use of television as a teaching aid, or we can allow our imaginations to open up. Let us accept the risk of poor accuracy in prediction and even the risk of exaggeration in order to make a point. We shall describe a technically feasible, even though in some other ways perhaps unacceptable, "modern" high school of the future. But in doing this, please remember that I am neither predicting nor recommending the school I am about to describe, but only using it as a vehicle for making some points later.

School days

First of all, we will get the student registered. I won't burden you with the details here; when the registration is complete and the course of study suitable for that individual has been determined, the student receives a specially stamped small plate about the size of a "charga-plate", which identifies both him and his program. (If this proves too burdensome for the student, who will be required to have the plate with him most of the time, then we may spend a little more money on the installation and go directly to the fingerprint system.)

When this plate is introduced at any time into an appropriate large data and analysis machine near the principal's office, and if the right levers are pulled by its operator, the entire record and progress of this student will immediately be made available. As a matter of fact, after completing his registration, the student introduces his plate into one machine on the way out, which quickly prints out some tailored information so that he knows where he should go at various times of the day and anything else that is expected of him.

A typical school day will consist of a number of sessions, some of which are spent, as now, in rooms with other students and a teacher, and some of which are spent with a machine. Sometimes a human operator is present with the machine, and sometimes not.

A fundamental limitation

One thing needs to be said at the outset. Any attempt to extend the teaching staff with any kind of mechanical aids would appear to have at least one very fundamental limitation. It would seem that, unless a highly intelligent, trained, and authoritative teacher is available, there is no equivalent way of adapting the material to be presented to the individual student's need, or to judge the understanding and reception of the material and adjust it to the student during the presentation, to discover his questions, weaknesses and misunderstandings, nip them in the bud, and otherwise provide the feedback and interaction between teacher and student that is so essential in transferring knowledge from one person to another.

It is for this apparent reason that, although we can use motion pictures and television to replace a lecturer and can, in theory at least, be more efficient in the use of one skilled teacher's time, enabling him to reach a larger audience, we can only use such techniques for a limited fraction of the total school day. However, you will see in the systems that I propose that, in principle at least, modern technology can go a long way toward removing this apparently fundamental limitation. The whole objective of everything that I will describe is to raise the teacher to a higher level in his contribution to the teaching process, and remove from his duties that kind of effort which does not use the teacher's skill to the fullest.

Let us follow a student who is including in his schedule a course in trigonometry. He will spend a few hours a week on this study in automated classrooms. In the case of trigonometry, only a small part of his time need be spent with a human teacher. Some of his classroom exercises will involve presentation of basic concepts in trigonometry in the company of other students in short lectures, delivered by a special sound motion picture, which uses some human actors who enunciate or narrate the principles to the accompaniment of various and sundry fixed and animated geometrical diagrams.

Push-button classes

However, this classroom has some special equipment. Each chair includes a special set of push buttons and, of course, that constant slot into which the student places his identification plate. The plate automatically records his presence at that class, and it connects his push buttons with the master records machine.

If the class is large, our student is much less likely to sleep or look out of the window than in a normal lecture by a human teacher, because, throughout the motion picture that presents some phase of the fundamentals of trigonometry he is called upon to respond by pushing various keys. He is asked questions about the material just presented, usually in the form of alternatives. Sometimes he is told that the concept will be repeated and the question re-asked, this time for the record. He may even be asked whether in his opinion he understood what was being presented.

Special handling

In other words, he is in constant touch with the "teacher"; but something else equally important needs now to be added. His progress and score are used by the electronic master scheduling device to prepare for the special handling of that student in the other portions of the trigonometry course.

At certain other periods during the week, this student continues his trigonometry instruction in a different kind of environment. This time he is seated in front of a special machine, again with a special animated film and a keyboard, but he is now alone and he knows that *this* machine is much more interested in his individual requirements. It is already set up in consideration of his special needs. It is ready to go fast if he is fast, slow if he is slow. It will considerately repeat what he has missed before and will gloss over what he has proven he knows well. This machine continues the presentation of some principles and asks for answers to determine understandings. Based upon the student's immediate answer, it may repeat or go on to the next principle.

With some hints and assistance by the lecturer in the movie, and with appropriate pauses (not accompanied by a commercial), the student is allowed a period for undisturbed contemplated thought before registering his answer.

The machine's job

This machine is prepared to take a single principle and go over it time after time if necessary, altering the presentation perhaps with additional detail, perhaps trying another and still another way of looking at it, hoping to succeed in obtaining from the student answers that will indicate that the principle is reasonably well understood before it goes on to the next one.

Before the student receives the material from this machine, it will have rapidly selected from its file the appropriate films for presentation. These films are already set up with a number of alternatives at each step, and with such inner workings that the machine is prepared to repeat, advance, or substitute material determined by the student's performance.

You will see from this one example that we are placing the machine and the subject matter in contact with the student, and vice versa, in a feed-back relationship. Of course, we do not cover all possibilities; we do not even cover every possibility that a human teacher dealing with that one pupil could observe. But we handle a great many of the more common ones; we will strive for a very efficient and dynamically interesting presentation of a large amount of the material; we will do a very efficient job of examination of some of the student's understanding.

The teacher's role

A brilliant student could romp through trigonometry in a very small fraction of the course time. A dull student would have to spend more time with the machines. The machines can be so set up that, if a student fails to make progress at the required rate, he can be automatically dropped from the course. Of course, before that happens, or before the brilliant student is allowed to complete the course, a special session with that student by a skilled teacher is indicated. But the teacher will be aided by having before him the complete records of what could be weeks of intensive machine operations.

This will make easier a personal study of that student's understanding and his way of thinking about the subject. The teacher will even be able to judge in what way the operation is inadequate and needs to be supplemented, both to take care of that particular student and to improve the automatic techniques. Some students will learn better than others with these machines. Ultimately, with the proper cooperation between experts in education, expert teachers, experts in trigonometry, and experts in engineering these automatic systems, we can evolve that high level of match between the human teacher and the machine that we seek in that improved high school.

The memorizing machine

We can further illustrate these concepts by other special cases. Let us take the memorizing machine, for example. It is important in many studies to do a certain amount of memorizing of facts and data. As a scientist, I know that a facility in study of an advanced subject oftentimes requires that background information be instantly available to the mind. But what a drudgery it is to memorize the weights of all of the chemical elements! In fact, about the best way to do this kind of memorizing is to get help from another individual, who sits with the facts spread out before him, and before whom the memorizer attempts to recite.

The memorizing machine could remove much of this drudgery and make it interesting and efficient. For instance, for the series of chemical elements, the machine could go through the list while the student punches out the corresponding atomic weights on a cash-register type of keyboard. When he misses one, not only does the red light go on (and the sign say "TILT"!), but the machine remembers that he has missed it. As it continues to chase through the list, it will throw in some of those questions that the student has already answered correctly, just to be sure, and to give him the repetitive exercise, but it will more often come back to those where he had trouble previously.

A few minutes a day spent with memorizing machines, each of which is equipped with thousands of records to cover the important information to be memorized about various subjects, will probably accomplish more for the student than much more time spent in other ways.

Of course, it should be clear that this type of dynamic teaching and studying requires such a concentrated effort that it could not be used as the exclusive and total diet of the student, even if it had no limitations whatsoever. However, before we discuss these limitations, and before we try to make certain that we understand the fundamental difference that this kind of technical development could make in educational processes, let us take one or two other examples.

Machines in the laboratory

It is clear that the use of machines in which the student and the presentation are in responsive communication should be helpful in the presentation of theoretical concepts in science and mathematics, in the learning of basic principles, and in the acquisition of information in most other fields as well. But what about such things as chemistry laboratory, English composition, and the teaching of languages?

Let us take the chemistry laboratory first—and remember that we are speaking here not of the principles of chemistry in the theoretical sense, which would be handled much as in the case of trigonometry, but rather of the physical handling of matter in the laboratory and the acquisition of appreciation of the scientific method of observation and deliberation. I think much can be done here.

Teaching on film

Picture, first, the student seated again before a special viewing screen and certain apparatus. The chemistry professor in the movie has the equivalent apparatus in front of him. He turns some valves and allows some fluid to go into a container. He adds to this another different fluid. He observes the characteristics of the combination, he refers to the theory, he describes what is happening and why it happens. He then asks the student to turn the valves in front of him to let so much red fluid into the glass below, and so much blue fluid into the same glass. He tells the student that, if he has indeed poured the right amount in and observed every other requirement as described, he can expect certain results.

To show the possibilities, imagine that the instructor suggests that the liquid should be pink and asks the student to push button A if he has obtained this result, and button B if he has not. Now let us suppose that the student pushes button A. The moment he does this, the film immediately switches to one in which the professor points an admonishing finger at the student and says, "Oh, oh, oh—now look at that liquid! That isn't pink. You were simply led by suggestion to expect the result. You didn't use your own powers of observation. Clearly, if you look honestly at that liquid, it is, if anything, slightly on the yellow side. You must learn the first principle of science. That is to be honest—not to expect a result, but to seek to observe what result you do indeed have and report it accurately."

Teaching English

On the other hand, if the student refuses to push button A and pushes button B instead, a different film will congratulate him on being objective and having the necessary characteristics for the scientific approach. It is quite possible for experts in chemistry and education, I believe, to create a large number of laboratory setups that can easily be kept full and ready by operators, so that the student can conduct his laboratory experiments without detailed supervision, and with great efficiency and good records.

Teaching English and composition is difficult, as is instilling into one an appreciation of good literature. But even here we certainly can add to the exposure of the student to good literature and, by probing the student's understanding and response, we can alter the speed and nature of the presentation. We can improve his knowledge of the tools of good expression so that we leave only the more creative aspects (which must rest at least partially, presumably, on these tools, and on the knowledge of the characteristics of good literature) to his personal contacts with the skilled teacher.

Teaching foreign languages

Similarly, in the teaching of languages, vocabulary improvement, grammar, and understanding the spoken language could be advanced by these feedback machines. Even the ability of the student to speak the language could be enhanced by machine. He could respond orally to the animated film in front of him, repeat the foreign words spoken to him by an expert into the microphone, play back the results immediately and repeat the whole process. This, you see, goes a substantial step beyond the use of records, which I understand is quite common in the courses now available commercially for learning foreign languages the "easy way."

Let us see what physical and human resources this high school would have. To begin with, the physical plant would include a large amount of apparatus that does not now exist, but that can be designed and constructed with today's art.

There would be administrators and clerks who would handle all of the administrative processes, but who would not be at all concerned with, and not be trained in, education. There would be a group of highly skilled teachers. The more conventional type of teaching would still be a substantial part of the total operation. For the new, automated material, these teachers would work closely with the experts on the subjects, and with the education engineers who design all of the electronic equipment that is basic to the process.

A new industry

To back this up, of course, one would have a very substantial new industry in the United States concerned with the creating of these educational machines and the motion pictures and memory data used by the machines. In general, the industrial organizations concerned with the creation of machines that make possible the teaching of mathematics would have to employ experts in education, experts in mathematics, and experts in engineering. And this industrial team would have to be in good contact with the skilled teachers who make up the high school staff, in order that they might be able to improve their machines, create the proper material, and learn the shortcomings of all of their designs—either of the machine or of the material.

In addition, the high school teaching staff would include education analysts, probably specializing in the various subjects. These individuals would go through the records of the individual students. They would be constantly seeking to discover the special problems that need special attention, by the direct contact of teacher and pupil.

We notice a number of very significant points here. The high school becomes partially transformed into a center run by administrators and clerks, with a minimum of the routine assigned to the teaching staff. The teaching staff is elevated to a role that uses the highest intelligence and skills. A smaller number of teachers make possible the education of a larger number of pupils. The creation of educational material moves partially out into industry, which goes into the education business in partnership with the educators.

A new profession

There is probably a new profession known as "teaching engineer," that kind of engineering which is concerned with the educational process and with the design of the machines, as well as the design of the material.

One might imagine, for example, that a course in solid geometry, with its three-dimensional patterns, would be based around 3-D animated communicative-response systems, and that some of the experts on the teaching of solid geometry should better be employed in industry than in the school. Those teachers who would be employed in the schools themselves would be individuals able to handle the more difficult problems that are left for the human teacher and the analysis of the processes that involve the use of the machine.

From the standpoint of the student, I no not know that his life need be changed in any fundamental way. It may be, of course, that the evenings and weekends would cease to be times for doing homework. The equivalent of homework, as well as the basic presentation periods, would be done perhaps during the normal working day, five days a week, with the evenings and the weekends used for the broader cultural, social, and athletic events. That is, the evening would be a time for a more relaxed participation in the learning and broadening programs.

I think it is true that, with this kind of an educational system, the student need not feel that he is dealing with cold machines in place of warm human teachers any more than he feels that way today when he reads a book by himself instead of listening to an oral presentation by a human teacher.

An expensive operation

It is interesting now to look for a moment at the economics of such an educational system. In principle, it obviously has application to the lower grades, and certainly to the university as well. But, wherever it is applied, it is quite easy to show that it is an enormously expensive operation.

Use that course in trigonometry, for example. As a motion picture, it would involve not one hour or two hours but, say, one hundred hours of expensive teaching material. Unlike a motion picture, it would not be viewed by tens of millions of people all over the world. The audiences, for the most part, would be small, and unless we could unite all trigonometry students for a number of years in the common use of this same material, it is apparent that the cost would be rather large. If we pay something like 50 cents an hour to see an ordinary motion picture, then a trigonometry course would cost thousands of dollars per student, and the complete high school year would cost tens of thousands.

Slaves and machines

If we reflect for a moment on this matter of economics, we are reminded again that something is very wrong in the balance between that part of the national economy we devote to education and the part we are willing to devote to other things. To bring this point out, let us use the analogy of the Egyptians building the pyramids by the use of thousands of slaves pulling huge rocks—that is, by the most laborious and inefficient way possible in terms of the use of human beings. We imagine that we could have walked up to the Pharaoh and said, "This is not the way to build your huge monument. For this you should use bulldozers and cranes and steam-shovels; why, a handful of men and a handful of machines would replace your thousands of human operators." But then the Pharaoh would have said, "Ah—but will it save me any money?" So we would figure it all out and discover that it would cost him much more if he changed to the machines because he paid his slaves so little.

In this system that I have described, we seek to elevate the teacher to the exclusive use of the higher abilities and qualities he possesses. It is a system that makes possible more education for more people with fewer skilled teachers being wasted in the more routine tasks that a machine should do for them. And we come up against this economic question. Today, the teachers are doing all of these things—the routines, and the handling of those levels of teaching requiring the highest of intelligence and training—and they are doing them for less than the cost of the machines, which could only hope to replace the lower level of the teaching art and skill!

A ridiculous idea?

The examples I have presented here illustrate what I think is the most important point that can perhaps be contributed to a discussion of the relationship of the technological revolution and the educational process. While being defensive about these specific ideas, I won't go so far as to say that there is nothing in them. My work has accustomed me to the idea of being willing to allow imagination to roam freely, and my associates in science attribute a quotation to me which goes something like this: "Don't be ashamed to propose a ridiculous idea. Though worthless today, in ten years it may be of no value whatsoever."