Programmed Learning

The state of the Art in the United States

By

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I want first of all to say how pleased I am to be here and to have the opportunity to widen my horizon with respect to the kinds of problems that are confronting us in education. I think one tends to develop a rather provincial view of education when one concerns oneself only with the problems existing in one's own country. Obviously, education is a world-wide phenomenon and the pressures around the world are extremely critical. I think that cultural differences in education are an important factor in determining the course as well as the content of education, and I feel it is important to say something about the background within which programmed instruction and teaching machines really became formed and developed in the United States.

I bring this in at the beginning because I feel that it is important to realise that we are dealing with materials which have many subtle and possibly unrecognised features that could provide difficulties if transplanted. It is quite easy to identify the fact that you have bought a car that steers on one side rather than another. This is quite obvious. When one buys a programme or a machine or a combination, which, of course, is what one really needs, then, of course, the problem is much more difficult than the case with the automobile, and I feel that it is important that we look at some of the background, not because it will be possible thereby clearly to specify the differences which should be taken into account, but mainly to set up a red flag, so to speak, to indicate that one should be cautious and careful.

In American education there have recently been many challenges, some of these much more than others. We have found for example that at the collegiate level, college professors, some of them men of great reputation, became concerned in the course of their collegiate experience with the kind of student that was coming to the university, and consequently many of them became sufficiently interested in the curriculum of the high school to develop actual teams—not just individual activities, but teams of men—who set about, as an important part of their professional life, to re-design high school and even grade school curricula, particularly in the sciences. You probably know of the "life adjustment period" in American education which was placing main emphasis upon the adjustment of the individual to and in a new society; this, of course, was quite an important notion when you had a large number of immigrants from other countries coming to a new country and having to rub elbows and work together and work out problems which many times were the simple result of cultural conflict.

That era is recognised as having passed and it has left in its wake the problem of a deficient and rather anaemic content in the various courses, most obviously in the areas of science. This was not wholly a life adjustment result, but also I think, in an important respect, a result of the fact that science itself marches rapidly, in fact takes off at quite a rapid pace—it has been estimated, for example, that science regenerates itself about each decade at the present time, so these factors have developed an important challenge to education. The educator had to do something about these problems and he was not alone in his concern or in his efforts and was greatly supported not only by individuals initially, but by our National Science Foundation which has devoted large sums of money to the reworking of the science curricula

In examining what might be done to the sciences, there was great concern about goals, and the goals have changed very markedly from what they were in the past. We have taken what might be considered a ninety-degree turn in defining the goals of courses in the sciences. At one time the content was extremely important. The scientists who examined this problem under the conditions I have described quickly came to the conclusion that the only enduring thing about science was

scientific thinking, the thought patterns, the way in which scientists approached their problems. Scientific discipline, in the sense of a mental discipline, seemed to be the prevailing orientation towards a redirected curriculum. In other words, the goals were no longer to teach a jumble of facts and to make the individual able to apply science immediately but rather what they felt was critical and most important was to separate out the conceptual structures that were important in each of the sciences, make these salient by the very way in which one wove the fabric of the factual and conceptual material. So the actual content became the handmaiden or the vehicle by means of which scientific thinking was to be taught.

This is still going on. It has not developed completely, but it is a predominant form of goal and objective, and a major characteristic of practically all of the curriculum revisions in science that are going on. In physics it is the orientation toward the atomic structure. In chemistry, one of the dominant orientations is towards the chemical bonds, the nature of the bond joining the various elements and so on down the line in each field. In biology, the various structural concepts of organisational ideas are the focal point of the instruction and the material, actual factual materials are used to illustrate and develop within the student this conceptual structure.

One of the other problems besides all of this curriculum revision and movement toward change in the actual courses that are being taught, was a rapid realisation that we couldn't train all of the teachers that we needed to meet the population explosion that was developing rapidly. Not only was population growing, but we were finding many more students wanting education, continuing beyond the minimum requirements that are imposed by law. Consequently the question arose as to how to cope with this problem. You are all familiar with educational TV and its development in our country. We feel that this has had some impact and is continuing to do something for the educational problem. It has not been used to train teachers as extensively as it might be and I think this is one of the deficiencies.

We see here a crisis in which we need to expand our education, and probably the initial focal point of that attempt to expand should be in the training of the teacher rather than in the training of the students. By getting at the teachers we can then multiply our efforts, and so teacher training was challenged. Not only were curricula for school-children and the curriculum at the collegiate level modified—once you modify the high-school curriculum, you force things downwards that were at one time preserved for college, you immediately change the college curriculum, then you also have the problem, as I have indicated, of training the teachers and developing these procedures to a more efficient and effective level. Many people have thought of course, that one of the solutions was not to go to all of this hardware, not to use educational TV and programmed instruction, but rather to find the genius teacher.

This concept prevails and is frequently voiced. I feel that it is a voice in the wilderness, unfortunately. It would be, I think we would all agree, ideal, if we could find the genius teachers that we needed in the numbers that we needed and have them in the places we needed when we wanted them and had a requirement for them. But this just doesn't happen and so we have, I think, to look toward some other way of accomplishing our goals, and automation, of course, has been one of our main solutions to problems in other areas. It is somewhat surprising, in a way, that it should come to education at the tail end of the line. But nevertheless, I think it is here; I think it is here to stay. The question is whether we can cultivate it and develop it so that it becomes an instrument of progress and of actual future growth rather than something by which we will be enslaved.

These then represent some of the currents in the American educational crisis. I would like to talk about some of the activities now to give you a kind of topographical picture of what is going on. This is what was going on, as I saw it, before I left the States—I arrived here on the 17th April and I imagine that by the time I get back, the picture will be greatly different. So by the time this monograph or paper gets typed and is out, everything in here will probably be untrue. For what it is then, I will try to describe it as I saw it as we were taking off from the airfield, leaving the United States for South Africa.

One of the points, I think, that we find in the U.S. is that we are a democracy in the broadest sense of the word, certainly in our educational practice, and consequently there is no one defining or controlling group which determines the actual nature which any set of ideas relating to education will actually take. There are, of course, determining influences, as there are in any society, but to try to describe the pattern which programmed instruction has taken in the schools, for example, would be sheer nonsense because one could go into many schools which would not even have heard of programmed instruction in the United States and one could go to schools where programmed instruction was not only heard of, but where the bit was taken in the teeth of the leaders in that field and they were going off in a very different direction from any other direction one could identify elsewhere. So one has to be cautious then in trying to describe the situation.

All I can do is to give you some of the more salient aspects of it, some of the things which I happen to know about, simply because of communication or personal contact with the groups.

Having established the fact that there is no uniformity, let me talk about some patterns that do exist. We find, for example, and I think this would be a useful concept to keep in mind, that the pattern and the use of programmed instruction is determined to a considerable extent by the availability of programmes. And so, what will be done is determined by those who produce these new materials. So we have here the central core. The actual applications, however, do deviate from those which were possibly prescribed by the developer of the programme or those used by him—whether he prescribed them or not may be another matter. But we find in terms of availability in the States, programmes mainly for the more verbal, more literate groups; in other words we find a kind of upside-down triangle, if you will. If you took a line going horizontally as representing a frequency bar of the number of hours of programmed material or the number of frames of programmed material, however you want to measure it, and you start with the upper grades and go down to the lower grades you'd find that this diagram would taper off like an inverted triangle; in other words, for the higher grades, you find more material, for the lower grades, less material. You find when you get down to kindergarten level, there's very little material available—especially for education dealing with the mentally retarded, deaf, blind and so on; there's very little in the way of available hours or frames of instructional material. So one would infer from this, on the principle I have just stated, that programmes are used mainly in the eighth grade and above.

In respect of subject matter, probably the widest variety of materials is available in the eighth and ninth grade mathematics. I think to some extent this is due to a combination of factors, not only that mathematics appears to the novice as being a very appropriate and convenient subject matter to use for programming, but also the curriculum revision programmes that I talked about have tended to think in terms of revision at that level. The underpinning notion is that something that works at the eighth and ninth grade level, for example set theory or mapping concepts and so on, can possibly be moved down, and the question what we do with those who move up is clearly defined. So you have both directions in which you can expand your concepts and ideas, and so choosing a middle group to introduce an innovation has some strategic advantages; for this reason this has been a kind of focal group for mathematics, English programmes, our social studies programmes, and so on. We find foreign languages of rapidly growing interest as an area of programming. Within the English language itself, spelling, punctuation and poetry are covered by programmes. In the natural sciences there are several programmes going up to the collegiate level, and we find psychology, logic, statistics and a programme teaching people how to use the library, which has been quite effective and seems to have a great deal of promise. You find such topics as deductive logic, thoughtful reading, formation of concepts, trouble shooting in engineering courses, applications of electronics, reading of radarscopes. We find programmes that are designed to provide the hard core of instruction on their own and we find programmes developed as adjunctive or supplementary materials to the use of other means of instruction including educational television as well as live teaching and standard texts.

So one sees then an activity pattern of a rather varied sort in the U.S. schools and colleges. In spite of all the activity in programme development and the apparent widespread application, one sees surprising lack of progress in another direction. The Centre for Programmed Instruction in New York City reported some data from a survey which they recently completed. Their report was, I think, surprising in many ways and gives you something of a different picture. They surveyed some 14,000 schools, received back a very small number of replies—about 2,000—and they found that of these about 1,700 roughly were non-users of programmes and only a little better than 200 were actually employing them to any extent at all. The survey asked about the knowledge which the users had of programmed instructional material and they got again, I think, some interesting information, that during the 1961/1962 period, mathematics programmes, as I have already indicated, were the most available and most widely used. These cost somewhere between ten and fifteen dollars per programme. They were re-used several times so as to make their cost spread over a large number of students. Seventy-three per cent of the users of programmed materials employed programmes without machines, eighty per cent of the schools used very few students or very small groups of students on a trial or preliminary basis. Seventy per cent were incorporating programmed instruction into courses in one way or another, to a greater or lesser extent, the extent not being defined. Forty-eight per cent used programmes in class, that is the student came to class and used the programme as opposed to using it in the study hall or at home. Fifty per cent of the teachers were available as active supplements to the programme. Forty per cent of the teachers acted as proctors and answered

questions of the students when they arose. This gives you an idea of the pattern of use. It is by no means a very representative survey in the senses I indicated. We don't know about those not replying and we don't know what the patterns indicate. It may be that those not replying are non-users. There are a number of possibilities here obviously.

What about the effectiveness of programmed instruction in schools? Studies have been done and are being done, often under the initiative of the school system itself. For example, in Denver, there is an active group working with Spanish and English programmes throughout the entire school system and we find a new school being formed in California where individualised instruction will be the entire pattern of the school. The whole school will be devoted to this concept. We find this not only in the elementary level in California, but if we move to another active and competitive state on the other side of the country—Florida—we find a university going up whose concept is the same—one devoted to the use of the new media as it is called, not only programmed instruction, but educational television and the rest. All of this will go into a central facility costing several million dollars and will be the first to be built on the new campus. In this institution it is planned that a college professor's life will be that of a questioner, an individual tutor, who will discuss problems with individual students, but the main burden of instruction will be accomplished by the various resources that are available through the modern media. We see these patterns developing and we also see some evaluative studies done on a preliminary basis within the schools.

One study, for example, reported by Smith and Quakenbush indicated that a gain of half a grade level in arithmetic was produced as measured by the California Achievement Test with groups of 23 slow learners, mean IQ of about 77. The previous year was a basis for comparison, and they showed that in the previous year, instead of half a grade improvement comparable children improved only about two-tenths of a grade level.

Other programmes seem even more effective for the high-ability students than for the low-ability students, but I think in general the pattern with ability level seems to be that the greater impact is with the lower ability groups. With our UICSM material (University of Illinois Committee of School Mathematics), which is one of the early curriculum revision projects in mathematics, started about ten years ago by Professor Beberman and a group of educators and mathematicians, the programmed version is primarily for the college-bound student; what we did in our first year of programming was to look at a large number of schools whose student populations differed rather markedly, from an average of about 90 IQ up to about 139 IQ to see where it was most effective. These are class averages. So you can see a rather broad spread of student ability was covered. What we did was to look at the performance of the students—matched groups—in terms of the teacher-taught groups versus those taught by both teacher and programme. So we had students taught by teacher alone, compared with those taught by teacher and programme; what we looked at was the gain in performance of the group in relation to intelligence. We found that we got increasingly more effective performance from the programme as the IQ went up from about 110 to 120; at 110 it started to show bigger differences and then as the IQ went up, the differences between the teacher and the combined condition spread. Here is a set of programmed materials, in other words, which were being written primarily for the more able students rather than for the less able students. But in general, this is not the case.

In industry in the United States, we find some other kinds of information. Again the pattern is not clear—a survey of the 500 leading corporations showed rather spotty application of programmed instruction at least in terms of the reports that were tendered back. What this means, of course, is not entirely clear because there hasn't been a follow-up visit to the organisations to actually determine the nature of the applications in detail, Some companies bring in consulting groups to help them develop programmes for their particular needs. Others are developing in-house capabilities so to speak. They are trying to develop and train their own people to produce programmed materials and there is a variety of companies working on this basis. If there is a general pattern, it seems to be one of diffusion of programmed instruction into industrial training generally; it does not follow along any particular industrial lines. No particular industry seems to be more outstanding in this respect than any other. Electronics, probably because it is new, has grown rapidly and has a large personnel turnover, is making use of this medium much more than other industries which have more stable personnel.

I don't know what the position is in this country, but in the United States, the training directors are frequently drawn from elementary school and high school, and frequently these are individuals who are skilled in some related area to that of concern to the company. They take over the responsibility of developing curriculum material for particular jobs. These people have not taken to programmed instruction to anywhere near the degree of intensity that I would have expected. On the other hand management in U.S. industry

is keenly interested in programmed instruction. The American Management Association has held several major conferences on both coasts and smaller ones in other locales. In general there has been a very keen and a very strong interest in understanding the concepts and their application. I think that eventually, this education of the higher echelons of management will diffuse downward into the training departments, and one will see a greater development of programmed material. For skilled, semi-skilled and unskilled labour some applications of programmed materials in the training of management itself has been reported. There have also been programmes developed to teach such things as interviewing personnel and programmes to train people who are working on the stock market. I tried to get hold of that programme on the stock market but I wasn't able to. They kept it under very close surveillance. Instructors in I.B.M. reported that a class of computer programmers who were taught by programmed instruction achieved their level of competence in about half the time that was normally required by the conventional means previously used in the company itself.

Other studies have reported no difference in the amount of learning of basic electronics concepts from machine teaching as compared with conventional class methods. You find in general that this is not the pattern. Usually better performance is achieved with programmed materials or time is saved. Time shows up as one of the bonuses one gets from more effective teaching methods; it seems this is more frequently found than differences in the actual achievement scores on test. In industry and in the military, programmed instruction has been used to train trouble-shooters —people who find faults in various electronic systems. The programmed instruction techniques have been compared with the use of mock-ups; which are conventionally used—mock-ups are panels on which equipment is mounted—and an individual is given problems which he traces out on the panel. In lieu of the actual equipment this technique is a fairly standard and accepted one, not only in industry, but also in the military services. Again the programmed instruction groups in the studies that have been reported frequently are superior in actually understanding the troubles—this is the nature of one finding—but they were not necessarily superior in the actual use of equipment in the detection of the trouble.

So one finds that by the method of programming or the method of instruction, there is some differential impact on the student, in the sense that it tends to favour or give some specific benefits rather than across the board benefits. This, of course, is fertile ground for further inquiry because it begins to give us the kind of leverage we need, namely, to know when to use various techniques; of course, this is a kind of symptom that I think is quite critical and suggests further enquiry is needed using fundamental research in the discovery of the nature of the interacting effects.

Within the military, the largest-using group is the Air Force. This is quite distinct in its pattern of development and use and I think can be traced mainly to the personality of the prime mover, Colonel Olfeisch. He is a very dynamic individual who isn't easily dissuaded from his views and who uses all the resources available to him to develop programmed materials in house. They are developing their own group of personnel. They have set up training programmes for their instructors. I am not sure of the method of selecting them. They have arranged for training at various locations around the country and they come to our campus, for example, and get an intensive lecture series. Then they go back to their jobs and are given particular areas to work in and they work as teams to develop programmes. These are then reviewed and tried out. They are developing procedures for processing the materials—a well-developed and large-scale operation, probably producing the greatest diversity of programmes of any single group that I know of. None of these is available commercially. They are used within the Air Force, sometimes dealing with classified gear which is frequently specialised in the sense that this would be the type of equipment used by the Air Force to accomplish their mission. This does not mean, however, that they don't teach mathematics or English and the various fundamental topics as well. It is simply that the main effort, the largest proportion of the three hundred odd programmes that are being developed within the Air Force, is of a more specialised nature. I don't know what the proportions are, but there will be information on that forthcoming fairly soon, because a survey is currently under way and being written up.

The Navy on the other hand has had a different plan in terms of an in-house development. However, Training Devices Centre, the Office of Naval Research, is supporting externally a number of projects which are being devoted to a variety of different problems in programmed instruction.

One study with Naval Reserve Officers who received about seventy hours of programmed instruction material reported that this small group of officers, about eleven I believe, learned as much Russian by programmed instruction and tapes during a ten-day period as others had in a full-time study in Russian for a semester or a semester and a half of collegiate work.

The army takes a slightly different approach to the problem. Again it does have contracting groups who are working on programmes, as research problems. They have civilian groups scattered around and attached to various of the army units. They are working with the specialised groups within the army and these groups are doing programmes as civilians attached to the army and housed and billeted right on its bases. They would work on programmes of concern to the group being trained at that base. This is their primary pattern of work in this area, rather than to contract with more remote institutions, such as universities, who might work on problems not necessarily closely tied to military operations.

What are universities and colleges within the States doing? Universities and colleges, like the schools that I mentioned earlier again show no consistent pattern. The effort in programmed instruction at the university level exists, it, like our laboratory, is made possible by contracts from a variety of governmental agencies, U.S. Office of Education, Office of Naval Research, and Air Force—these groups contribute funds, we submit proposals to them for research in the area, and we develop programmes, usually as part of a research effort, as a vehicle by means of which we can study a programming principle or a procedure for implementing a particular type of instruction. These research and development groups then would probably be the main kind of activity at university levels. But some schools have been far-sighted enough in their administrative staff and have had the resources from one means or another to actually set up research groups of the kind that the military have set up, particularly the Air Force, where they are developing programmes for use on the campus in anticipation of their rapid growth. There are different patterns here—Hamilton College, a small college in New York, was very early started in this way and has an active group in philosophy, French, German and psychology collaborating in this way. Earlham College, a small Quaker school in the mid-West is doing the same kind of thing. They have a team, a small permanent group devoted entirely to the administration and development of material and then various staff and faculty personnel come in on a voluntary basis to work on programmes relating to their particular area of instruction. The faculty selected areas in which they are interested in applying this procedure or where they feel there is an immediate need and important service to be provided by it. Usually groups of this kind are not developing new knowledge in programmed instruction as their main effort, although they certainly are not uninterested in that. Their main interest would be in the development of materials to be used at the collegiate level. Harvard, for example, in Cambridge, Massachusetts, has a committee on programmed instruction which is really a loose federation of departments with a small core of permanent staff—people who act as consultants to any department interested in trying to develop material. At the University of Illinois, where we are located, there is no such committee. Our group gets its funds, as I indicated, from research grants but we have tried to do the kind of thing I described. I have been meeting regularly with people in our music school who are interested in revising the curriculum in music theory. Groups have come in from the college of commerce or the school of medicine or dentistry and so on. These requests come spontaneously and on voluntary basis. The people come down to the laboratory, we give them the materials we have in our library and have eked out of meagre resources or are able to get one way or another. We let them go through programmes we have and then we hold small sessions with them to gradually develop their problems, define objectives and get them started. But all of this has to be done, of course, on borrowed time which doesn't exist and we can't, of course, use our research funds which have a definite purpose. To do so would be diverting funds to other functions. We do need funds for the self-development in university function. Hopefully, of course, simply by maintaining a kind of substantial contribution to the university, we shall acquire some of the funds which currently are being rapidly picked up to meet expansions in numbers.

We have some 20,000 students at the University of Illinois and our numbers are supposed to double by 1970; we are building a whole new campus in Chicago and breaking ground right now, and it will probably be the size of the Champaign Urbana campus within a couple of years after opening. So one can see the nature of the problem in the U.S. and, of course, the need to have universities building programmed materials to meet their needs. Incidentally, this new campus in Chicago has as its first building, a library in which we have designed a facility to accomplish programmed instruction, fifty individual stations are planned, and in the very near future, in about a two or three year period, as many as a hundred or possibly two hundred individual stations are anticipated. We are putting this in the library. We think this individual tutorial capability would be of service to all departments and therefore we did not want to locate it in any particular departmental building. The notion here would be that this would be used initially for courses where we don't have adequate staff to meet the instructional demand, where we have remedial requirements at a state university—

sometimes our minimum standards are lower than many of the faculty would like and so we have individuals coming from areas where the teaching staff in the elementary and secondary school is below standard in our estimation. Consequently it is necessary to accept students who do have deficiencies that have to be made up before they can advance and so the notion was that we could have the greatest impact with programmed instruction by putting it initially into a library facility, where it would get maximum use by as many departments as possible that we could interest in developing materials.

Studies have been done—I am sure you are aware of some—at the collegiate level, with university classes, to determine the effectiveness of programmed instruction. One of the earliest studies was a programme in German, not a very adequate research study, but it did demonstrate that it was possible to utilise programmed instruction and make it effective and acceptable to graduate students who are taking it on a voluntary basis. There have also been other programmes in other languages. Russian programmes are being developed rather rapidly for collegiate use—French and Spanish programmes and so on. Usually the effectiveness of these programmes is evaluated in terms of standardised tests. The reason for this is that one can then obtain a view of the relative performance of groups taught in a variety of means by using the same test for all different treatment groups. In this way, one presumably would not be introducing bias, although I think there is a great deal of caution needed before one simply takes a so-called standardised test and uses it. It could very well have been developed by improper sampling of content which could bias the results in one way or another. But in principle, I think, the idea is a sound one. It is a matter of the method by means of which the standardised test was developed, to ensure that in terms of its coverage it is representative of the various methods of instruction that are being compared, giving no bias to any particular method.

Logic has been a favourite collegiate form of programme and studies have been done with logic programmes. Some 8,000 frames were presented to a class who met and used such a programme as the sole basis of instruction; later the instructor carried on where the programme left off and according to the report, these students gained an average of 10 points in the final exam over what previous classes had achieved on the same material and with a programme prepared by the instructor of that course so that the content was comparable.

At the University of California in Los Angeles there have been reports of studies with some 186 freshmen, students, who studied an English programme and a programme in probability in statistics; the students in engineering who took the probability programme were compared with a variety of other teaching methods and the programmed instruction group performed better than the students taught by the conventional method. The results were statistically significant. In another study, there was a comparison between those taught by programmed instruction and the conventional method in psychology and again differences favoured the programmed instruction group when the main means of supplementation was a Pressey punch board used as an adjunct to the regularly taught programme or course; in addition, the programmed instruction group, the group getting the adjunctive material, showed a rather substantial proportion of A's in the final examination—I think 54 per cent of them.

Pharmacy students at the University of Pittsburgh were taught information about vitamins by the traditional lecture method and by programmed instruction, and were given an immediate post-test; six weeks later they were measured for retention, and the results again favoured the programmed instruction groups.

This gives you some of the patterns used by different groups in the United States who are concerned with educational problems. There are some other points that I think might be mentioned and might be of interest to you. I don't have very good information on some of these points, but I think what I have might be worth mentioning.

First of all, at the elementary level the use of programmed materials involving a piece of hardware has not been the predominant mode. This is primarily, I think, an economic factor. It is not that people have not been interested in the use of machinery, but rather that they have not been able to afford it. Consequently, there is a growing set of programmes available in book form of both linear and branching types. The linear format can be of two types—a horizontal pattern where you take a frame at the top of one page and go on to the one at the top of the next page and then you come down to the second level and so on, as opposed to another linear format which would be set up in a vertical format for a machine because the machine would move the paper vertically. So when one sets the type and generates a programme in printed form it is critical that the eventual nature of the binding or form of use be considered; but in general booklets have been used. We ourselves in our research are using booklets extensively because our schools are remote from our laboratories. We have to mail things out and we couldn't afford out of our meagre research budgets to buy enough equipment

to send out with programmes. I simply want to indicate here that hardware is in use, usually on an experimental basis to educate teachers, to give them some feel for its potential, to let students know what it is like and to stimulate interest and enthusiasm for the approach in a period of transition, in the hope that funds will be forthcoming for their more extensive use where really needed.

The dominant pattern in booklet form is a linear arrangement. Linear programmes have been the dominant form of programme developed in the States; I think, however, that they are gradually waning and that branching programmes are increasing, but more obvious is the fact that our programmes are becoming more and more mixed in form. There's less orthodoxy, there's less rigid maintenance of the particular style, except, of course, for research purposes. There, one has a reason for maintaining a pure style so that one can determine the effects of it as a variable and see what its potency is in determining the effectiveness of a particular approach. But for programmes in general use, I would say the obvious form in which you will see American programmes in the future would be of the mixed kind, where branching and linear styles are used, not indiscriminately, but with some thought as to where they might be most effectively employed.

I might mention something about cost. This data, is of course, hard to come by, and obviously the salaries one pays and various other factors will vary considerably from place to place, not only within our country, but from country to country. Sandia Corporation, for example, has taught Russian to its employees by conventional methods and estimated the cost per completion at 57 dollars and 15 cents. To teach the same amount of material in Russian to employees by programmed instruction, they came up with a cost per completion of 20 dollars and 19 cents, almost a third of the cost by programmed instruction. Algebra was taught conventionally at a cost of 20 dollars and 50 cents per completion and by programmed instruction by 16 dollars and 79 cents. The cost of instructors' salaries in general was the same for both of these since it was within the same organisation. With programmed instruction, each instructor could handle more students and therefore, it could be spread over a larger number and also with programmed instruction the company reported that they got a higher percentage of completions. So one sees the cost coming down in two ways.

From what I have said, there is little doubt, or should be little doubt, that programmed instruction can be effective; it can be used in what I call a broad spectrum approach. Educational television was originally developed from commercial television and used for entertainment purposes. Programmed instruction has been a development within education and for education, and I think this is an important difference. I think the other important difference is the spectrum of application. One can take a programme in printed form, in a booklet, out to a primitive village. One could take even some of the very simple mechanical devices since there are no power requirements. One can on the other hand get as elaborate as some of us are doing in our laboratories at the present time in the States and use computer-based systems, systems in which individual inter-face units, as we call them, are connected to a single computer. They are called inter-face in the sense that they are surface between the learner and the controlling mechanism. He is both exposed to material through them and responds to them through the inter-face. Units of this sort are connected to a computer, where, in our laboratory you may have as many as fourteen different stations simultaneously controlled by a single computer. Our Co-ordinated Science Laboratory has a two-man system now, but hooked up to a computer which could take many more. They have made extrapolations from time data suggesting that they would be able to go to a thousand students, each working individually at his own rate out of the same computer. This would mean that the computer would operate only a third of its time, which would mean that if one could increase the memory capacity of that computer, this number, one thousand, could be trebled. The hardware exists, in other words, to do this and furthermore in these calculations, it was estimated that as many as eight different courses could be taught simultaneously in this way. One group of students could be on algebra, another history, another English and so on, each going individually at whatever rate he wanted to.

This gives you an idea of the broad spectrum notion. We are talking not about future systems that could be developed, not systems in the sense that we would have to wait for technological improvements in our computers, but rather systems which, if the funds were available, could be put into operation say in a year's time.

The estimated cost with the computer-based system of our Co-ordinated Science Laboratory has been 10 cents per hour per student, that is not including the capital investment, which would be put into the computer and in the inter-face units. These would vary depending on the type of inter-face unit one employed and hopefully, with mass production, inter-face units will come down to a much lower cost than at present. I think many

of these units could come down if they were widely used and widely produced. They would come down almost immediately.

By broad spectrum, the notion is that you can apply this approach broadly to the remote individual who is isolated for geographic reasons or for health reasons—the individuals in hospitals, the special education groups who might be homebound for one reason or another, the blind, the deaf. Programmed instruction has been used very little with these people.

Then we find the very elaborate and costly initial investment, but possibly in the long run the most economical investment of the computer-based system which could very well be the pattern of instruction in schools of the future. These patterns, of course, have yet to be worked out and one of the problems is how to employ the different possibilities efficiently. A number of the other tasks that go on in the school besides instruction can be handled by computers. Obviously, students aren't in school throughout the day and the computer is available to handle a lot of the business of the school, the scheduling of students, the grading of classes and so on, and all of these functions put into a single equipment system could very well make it an economical venture, even though a costly one as an initial investment. This, of course, would not only be true for public schools, but could very well be true for industrial complexes where you have a large number of students to handle and a variety of individuals to cope with and where you have many patterns of instruction that are required and instructors are hard to find and difficult to keep at a uniformly high level.

I would like to shift round slightly and to give you, not the kind of pattern that I have been talking about, but rather some research results that have come forth from examination of ideas about programming. As you know from Mr. Goodman's comments, there has been a great deal of interest in programming by psychologists, who have been quite concerned with attempts to extend these 29 or 30 different learning theories into the actual way in which one would develop programmed material. As I have indicated throughout, there is no consistent pattern in the American scene. I suppose the conclusion you will come to is that Americans are completely inconsistent, and this is probably true. Whether this is healthy or not is a matter to be seen by the results we produce, but I do have a feeling that this is quite a healthy condition, simply because the whole business of programmed instruction is so elementary and so much in its infancy and unless we can encourage the application of a wide variety of thought and intelligence to the problem of programming, we will too easily become fossilised in a premature pattern that could prevail, but not necessarily be the most effective one. I think there is a great need to allow competition and to get an individual spirit of competition involved in various efforts. I would hate to see a single development in any community or any country, because I don't feel we are at a stage yet where we have sufficient knowledge to justify this. Now the problems that have been examined have come from questions asked primarily by psychologists concerned with a particular orientation toward the learning process, that is they have, let's say, asked themselves just how people learn, and then they have said that if we think that they learn in this way, then in the development of instructional materials it would be desirable and critical to take one course of action as opposed to another. Mainly the experiments that have been done have been comparative studies in which one method of teaching and one type of programme has been used in competition with another. I use the word "type" rather loosely. I simply mean that a variable as we would call it, a method of manipulating the material, is identified, made explicit, and then used in one way, with one set of materials and then in another way with the same content. Usually, of course, students are assigned randomly to the two variations, so that the factors of individual differences are controlled, so that there will not be any biasing elements due to the kind of people who are taught by one programme as opposed to the other. In other words, the usual kinds of experimental precaution were employed in the studies. I won't go into the details of the studies. First of all, I'll state the problem and then give you some general idea of the nature of the results.

One of the problems that has frequently arisen in thinking about programmed materials has been a question concerning the use of prompting. Prompting is a concept which can be traced back to Pavlov's "spitting dogs", as my students sometimes refer to them—the idea of conditioning. In the conditioning experiments, the basic model is to present something like a bell and then have something that is known to elicit a particular kind of behaviour—the experiment wanted in the case of the dog experiments it was salivation —and by coupling these two stimuli together and bringing them closely together in time, it pretty soon became apparent that the response associated with the second stimulus was transferred to the first. The prompt is like the second stimulus. In other words, it is the stimulus whose effect we know will tend to produce behaviour of the kind we want. But we want that behaviour to occur in the presence of some other stimulus. Let's say that if we show a child a picture of a dog, he says

"dog"; we show him the printed word "dog"—he does not say "dog". In other words, what we want to transfer is saying "dog" to the printed word "dog" and by combining the printed word with the picture we can get this transfer accomplished. The picture in this case would be the prompt. Now the question that is frequently asked in studies of programming technique is how to use prompts, how to employ them efficiently or effectively, and the procedure with which it has been compared is what has been called the confirmation procedure; this is one in which the prompt is omitted and the stimulus is presented and one waits for the behaviour to occur and then reinforces it by presenting the individual with something that confirms that that behaviour is correct or appropriate. So in a sense when prompting you are presenting the stimulus either as a means for eliciting the behaviour and when confirming you are presenting it after the behaviour occurs; the question is which of these orders or sequences is most efficient. This concept applies mainly to the teaching of a single set of associates, a single associative connection. This does not deal with the question of how you organise material in a programme and put, let's say, one word like "dog" together with another word and so on to build up prose patterns, but it deals with the organisation of material for teaching new associations. This problem typically arises in a Skinnerian linear type of programme. I think you will see from my explanation of it how it would emerge as something which would be a translation of the Skinnerian notion to the idea of a verbal programme, using verbal symbols and symbology on paper, because what you are essentially trying to do is to shape behaviour, you are gradually trying to modify behaviour through some manipulation of stimuli and the question is how you manipulate those stimuli and what order do you put these stimuli in to get a particular form of behaviour. In prompting, one is assumed to learn by perceiving the two stimuli contiguously. In confirmation one is assumed to learn by perceiving the stimuli, then responding and then quickly being confirmed or disconfirmed by the stimulus which follows the overt response. Several studies have reported that in paired associate learning, such as learning an English-foreign vocabulary, learning does proceed more rapidly when prompting is employed. That is using a prompting as opposed to a confirmation procedure, one can build up single paired associate relationships more rapidly. Furthermore, the studies with adults reveal that prompting without the overt response has often been more effective than with the overt response. This has been explained by the fact that by requiring the overt response, one is building in delays in the formation of the association, that is the association can go on more rapidly with a non-overt kind of behaviour than with overt behaviour. Consequently, the principle of contiguity or closeness in time comes into the picture. I am giving you a little bit of the psychological explanation that is offered as part of the theory behind these results for those of you interested in these questions, so that you get a little bit of the psychological background. The main thing though is that prompting can produce more rapid learning and confirmation slower learning.

We did a study, for example, in which we taught sight vocabulary to mentally retarded children using word/picture combinations, and what we asked was whether this would apply even though one were to build up the amount of overlearning to a high level and assuming we were interested not only in rate of learning, but also retention. What we found was one of the kinds of contradiction that typically is emerging when one examines carefully some of the techniques that are currently being used, namely, that prompting was, as others had discovered, even under high levels of overlearning, more efficient for learning, but confirmation at the high levels of overlearning led to better retention. So here we are, as educators, presented with a perplexing problem. Do we want rapid learning or do we want better retention? We would like both. We would like to be able to eat our cake and have it too. And so we are currently asking the question whether or not it is possible to make an appropriate combination of these two techniques so as to achieve an optimum level of both rapid learning, possibly not maximal but still more rapid than minimal, and better retention, again not maximal, but probably better than minimal. If we could get an overall combination that would work better than any pure approach then, of course, this would be the technique to use. When I say combination, immediately we are moving from a simple prompting situation, to the technique of vanishing or fading. In other words, whenever one does use prompts, it is quite generally recognised that it is necessary eventually to wash them out, to eliminate them from the programme, and the problem is how do you wean a student from the prompt. Obviously what you want is to be able to take away the picture so that the child can read the word by himself. This is the end behaviour or terminal behaviour so to speak. The question is when does one start vanishing the prompt and what kinds of rules does one follow. Partial prompting techniques and fading have been used as devices for getting at this question of removal of the prompt once it is in and has been used to advantage. We find that the picture is not at all clear here as to what rules one might follow in vanishing. We know that it is necessary, we know that rather wide variations in vanishing

nevertheless do produce a transfer condition, so that the behaviour is maintained, but we don't have any data which suggest any critical period or any definite pattern of change. A variety of patterns have been used with success in teaching, let's say the retarded, a sight vocabulary and so on.

I would like to talk about one approach to fading or vanishing simply because I would like to illustrate it with a little concrete material that I think might be helpful in seeing an approach. A study was done by Glaser in which he was teaching young children, five and six year olds, the colour names; he started out with a programme using colours in as many ways as he could. In other words, the letters of the word, let us say, "blue" were printed in blue. These were embedded in a blue surround and the material on which they were viewed had a blue border and so on. Now what he did as the programme progressed and the individual made his response was to change in colour or eliminate various of these and so gradually the colour was withdrawn to the point where letters appeared only in black print. Now this device seemed to be quite effective, that is, the children learned the colour names fairly rapidly. It was done, of course, with each of the primary colours. One might have some difficulties because one would introduce discrimination problems if one were dealing with shades and tints and so on. He did not investigate that problem but only the question of fading with respect to colour and teaching of colour names. But it shows one of the techniques that could be employed to implement the basic idea and then gradually to withdraw the prompt.

The context cues in prose have been used in teaching German vocabulary in a method which might be considered a kind of prompting in an interesting manner by a man by the name of Schaeffer. What he did was to write essentially a passage in English prose and then in that passage he would put in various German words—just individual words—starting out, let us say, with the article "the", he would put in "die", and then later on put in the German word for the noun that went with it and then gradually he built up the density of the German words within the embedded context of the prose passage and the individuals were required to read and translate, that is to indicate the meaning of these passages as they went through them. This seemed to be quite acceptable to the students. It seemed from all appearances to be an effective procedure for developing and using context cues as a basis for prompting the behaviour that he wanted gradually to improve the individual's facility with a new set of stimulus materials and by the end of the programme, of course, the terminal behaviour was to have the whole thing in German and the individual reading the entire passage in that language.

Still another approach to prompting is in the form of guided discovery. I mention this because I don't want you to feel that the technique of programmed instruction in general or the notion of prompting and fading is necessarily restricted to the more mechanical or rote aspects of learning. It does not seem to be that at all. Gagné and Brown taught ninth and tenth graders to devise formulae for the sum of terms in an unfamiliar number system. They used what we sometimes refer to and, in the monograph by Messrs. Barnett and Proctor you will see illustrated, the Ruleg system which essentially is a deductive system in the sense that we are dealing with the rule and then the "eg" which means examples, and what it means is that the rule is presented in the programme and then is followed by examples of that rule to show its application. That is one way of organising the logic of a programme. Another is to use discovery, where the individual is given some information which isn't complete and he has to put something in the pot, so to speak, himself in order to come to the conclusion. He has to derive from his personal experience and what is given him, a discovery of a formula or a concept or an idea or a principle and guided discovery would be discovery which would be progressively paced so as to give him little hints along the way and eventually lead him to the discovery in what might be considered in the jargon of the field "small steps".

All three were compared. Guided discovery was the best in terms of the learning effects produced and discovery was next and the Ruleg system worked out least well in this particular study. I don't know to what extent one can generalise from this. Obviously it depends on the effectiveness of the writer and the technique used in actual programming in the implementation of these ideas, but it does suggest, for example, that guided discovery which is a partial prompting procedure can be quite effective if used properly. This study then is, I think, of some interest in that it illustrates the application of programmed instruction to the general idea of more highly developed skills, the notion of discovery, and to an area of complete problem solving, so to speak, with the individual dealing with the number system which is completely unfamiliar at the beginning, but he is then able to work with it conceptionally as the result of the instruction given him.

One other kind of problem that has been of concern to psychologists and emerging again out of learning theory questions is the problem of the response condition. Here we have in Skinner and

in Crowder differences of opinion with respect to the role of response in programmed instruction. Skinner uses the overt constructed response, where the behaviour is gradually shaped—where you get a portion of the behaviour out and reinforce it and you get another portion of the behaviour out and gradually fill this up so that it tends to fit the pattern that one wants. In many situations, this is an effective procedure, but it is, of course, not the only one to use, and Crowder takes the position that with adult organisms at least and going down the line quite a bit below that, one can take prose in fairly efficiently written form, give it to individuals to teach them something and then sharpen this instruction by selective queries, selective questioning and by providing response to and providing a multiple choice question. So the response is different; in one case the emphasis is upon a constructed response, the individual types out the answer or writes it out in longhand and so on. In the other case the emphasis is on behaviour which you are developing which is really presumed to be intact in some molar form and then the individual simply uses a simple selection mechanism, such as pushing a button, to indicate that that response is the one that he prefers or feels is appropriate at this time.

These two approaches then suggest different things about the way in which one would utilise response in programmes and therefore they dictate in a sense the actual form of the programmes. They have a very different form or character to them and a different appearance. Both have been used rather extensively, many times of course without being subject to scrutiny and enquiry about their effectiveness. Various dimensions of the response have been examined however. We have studies comparing overt and covert response. By overt response we mean an observable behaviour and by covert we mean that the response is something we cannot see, but which is made apparent through some indicator activity. You can't see the response of the individual in solving a simultaneous equation, for instance, which he may do in his head, but once he has arrived at a solution, he will look at a multiple choice array and then pick the alternative there that matches the solution that he has achieved and the overt behaviour simply is the button pressing.

The first point I would like to make here is that one should not confuse the observable behaviour with what is being learned. It is quite apparent that when one does write something on paper there is a larger overlap with the process going on internally than when one presses a button, but a button-pressing or multiple-choice selection in a branch type of programme implies by no means a programme which involves no cerebration, no thought at all. The mediating conceptual behaviour that goes into the decision that you want this alternative rather than that one can be quite elaborate and, of course, not very apparent in the action itself, so we want to think of overt behaviour and covert behaviour in these terms in general and we don't want to confuse recall and recognition with either of these overt forms of expression either. By recall we mean the ability of the individual, given some minimal stimulus, to be able to generate a response, and this is done in both branching multiple choice and in constructed response, even though it is not seen or required in the multiple choice. With paired associates material, using overt and covert groups given instructions about the way in which they should respond to the material, we find that where vocal responses or written responses are demanded of the learner and he is an adult, in general the overt response group does not do as well as the covert response group. We are dealing, remember, with studies comparing individuals for whom the language of response is pretty well established as a habit pattern and one could very well ask whether there is any mileage to be gained from having an individual write out words that he already knows very well. Obviously one is building in a delay, and the delay which one builds in may be more critical than the additional practice given in making that overt response. I mention this and underline "adult" simply because I don't think one would want to teach a child how to tie shoelaces, for example, by not having him make overt responses; in other words we have to be very cautious in interpreting or generalising these results to all kinds of behaviour. I am talking about verbal programmes used with adults who already have the language facility. If you are teaching an adult Russian responses, Russian spelling or, let's say, the Turkish language or Sanskrit, where you have very different responses involved, either vocal responses or written, then possibly having the students make the responses overtly would have a very important effect, and obviously vocalisation and pronunciation of words in a foreign language is extremely important in shaping the vocal response pattern, so I want to be sure that we understand that when the response pattern is not our problem, but rather we are hooking up established response to some new cues, then having the overt response is trivial; it may also have negative motivation effect in the sense that the student gets tired of writing things down or saying things that he already can say or can write very well.

I would like to move on to constructed versus selected response studies. Here we have a comparison between the actual filling in of a blank

versus pressing, let us say, a button, as one might do with a machine like the Autotutor. Fry, in California, taught Spanish vocabulary with flash cards and found that a constructed response group was superior to the selected response group when this was a short programme—very short in number of frames—and that the time taken to train the individual was somewhat less under the constructed response than under the selected response. Coulson and Silberman found that multiple choice took less time but an equivalent amount was learned. Several studies have reported no differences between the two. Thus it seems that constructed response is probably to be used with caution and only after some rather deliberate analysis of the kind of situation in which one is working. I think that whenever one finds a variable that sometimes works one way, sometimes another and sometimes gives you no difference, then immediately it suggests that there are conflicting or confounding conditions present in the situation that one needs to identify. It is quite possible that in the case of constructed and selected responses the kind of thing that I have already mentioned is quite critical, namely the level of development of the response or behaviour you are dealing with in the individual, so you need to look at the behaviour you want to accomplish and the entry level of the individual who is starting that programme. What does he have in his repertory of skills? Knowing that and knowing where you want to go, you can examine the question of using a selected response or a constructed response. If you know that there are certain homophones between two languages, for example, and you know that he can pronounce these, obviously here it would not be so important to use a constructed response, but if there are some new phonemic combinations that do require practice, then you want the constructed response, so in a programme, let us say, within the same language, you might use different ones of these responses to accomplish different purposes and I think that is what these data tell us.

Reading versus responding—here we are dealing with a very similar phenomenon and, of course, the critics of programmed instruction have taken great glee in finding that individuals who just read a programme through without making any response tend frequently to learn as rapidly as those who are required to make some overt responses of the button-pressing sort or constructed sort. Whether one can generalise those results again, I think, is highly questionable. Obviously the terminal behaviour with prose in an educational programme would be the ability to read a book without any problems. In other words if you programmed the individual well in terms of his language skills he could then cope adequately with a normal book as we know it to-day and get the information out of it and be able to understand it and get the information rapidly. What we haven't done is to programme his skills to the point where he is able to do this adequately and so we have to look at the book as a kind of terminal position or terminal state which you want to move people up to. And if we do find some groups perfectly competent in this skill, it is because they have somehow or other been programmed one way or another and have come out at that level. So again I think interpretation of these meagre and preliminary results should be done with considerable caution.

In general, research is forcing us to think through educational problems at a more molecular level. Programmed instruction is forcing us to be more analytical, more consistent in our analysis, and is putting our ideas to a direct experimental test. This is its primary contribution to date.