SOME PRE-UNIVERSITY APPLICATIONS
OF COMPUTER SCIENCE

a thesis
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by

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§1: INTRODUCTION

Most people seem sceptical about the whole business of computers in education. They regard teaching as something handed down from the gods and their forefathers. Their feeling about teaching is that either you can or you can't. If you can't, you keep out, and envy teachers their long holidays. If you can, it is best to follow traditional methods, because education has been going on for hundreds and hundreds of years which is more than can be said for most things in the modern world. And they have a picture of a bespectacled and learned adult, surrounded by open-eyed youngsters, all eager to pick up the pearls which drop from his academic lips.

Therefore, why all the fuss? Most people fear computers and think that they will only increase the upheaval which is evident in the world of education just now. For the sake of those who feel like this, it is worth recalling the reply made by a visiting English professor at Harvard who, after an obscure lecture, was asked by one student what good he intended to accomplish by all this. He replied that he had never intended to do any good: he would be satisfied if he got through without doing too much harm.

§2: COMPUTER EDUCATION IN SCHOOLS

There are in the main three departments in which computers are impinging on schools:-

(a) administration;

(b) computer-assisted instruction;

(c) computer education.

The first will not be discussed in this thesis; and most of this paper will be concerned with the second. But since the last is also of interest and is at the moment making the greatest impact on schools, it will be discussed briefly first.

§2.1: The Place of Computer Education

Whether people like it or not, it is there. As far back as 1962, a text-book called "Mathematics: a New Approach" (1) was published for use in secondary modern schools. The photograph opposite the start of Chapter I in that book shows a Pegasus II computer. Chapter I itself is headed, "Electronic Computers, Binary Numbers." It discusses the use of binary numbers and the applications of computers. A couple of years later, a series of topic booklets for primary schools included a booklet on computers. At the other end of the scale, there is a book written in 1966 by six schoolboys at Exeter School. This is called "We Built our own Computers." (11). Another secondary school at Romford - and this is not a selective grammar school - has had its own computer since 1965, and since then has been running courses for school children, teachers and others.

So whether people like it or not, it is there. Computer education has already entered the schools in one form or another, and its introduction has been going on for some time. It is not likely now to retreat. Critics of modern syllabuses often feel that primary and secondary school children and their teachers should not poach on preserves which until recent years have been guarded for the universities. They probably feel that the prestige of a subject is lowered if it is vulgarised in this way. Teachers often suspect that the children they teach may be brighter than themselves; and now perhaps the technical colleges and universities are afraid because their traditional territory is being threatened by these young upstarts.

What place, in fact, has computer education in schools? First, there is a practical issue. The school-leaving age is soon to be raised to sixteen years. Quite frankly, some teachers are looking round for something different which will help to fill that year. Computer education is a possibility.

Next, tens of thousands of people will be needed in the computer industry in the next few years. According to the Department of Education and Science Report of 1966 on Computer Education (2), the demand for systems designers, systems analysts, programmers, operators and maintenance staff was likely to increase from about fifteen thousand to sixty thousand, i.e. to quadruple, in the following four years. Training evidently must take place in the technical colleges or in industry. But schools feel that they may be able to join in this programme of training, or at least direct the attention of their pupils to the possibility of working in this field, by introducing them to the subject in school.

Lastly, there is another and very valid reason. An impartial observer would think that many people today, perhaps especially women, perhaps especially the older generation, were brought up in the Stone Age. There are people about who seem to have a great fear of everything mechanical and electrical from a tin-opener to a hair-drier. These gadgets and machines and modern wonders have come to stay, and men and women of today must come to terms with them. So easily can the technologists and scientists become our masters. Young people and schoolchildren need not learn all about the workings of computers, but it is wise that they should know enough to realise what issues are at stake, and how computers can serve us. They should know enough to realise that there is no need to go about in an awesome dread of computers, enough to prevent them thinking that the whole thing is caused by Black Magic, enough to respect the power of the human brain which is, after all, the originator of the computer. Schools give pupils an introduction to Wordsworth, high jump, French, geography. The children are not expected to pursue all these branches of learning or skill very far, but it is to be hoped that their lives will be enriched by their studies, and if they want to pursue them later there will at least be a foundation on which to build. Silbermann, a computer scientist in the U.S.A., says: "We must include in their education the cultural and technical aspects of computers. Computer literacy is essential if the problems that will be presented by an automated society are to be solved."

§2.2: Work Being Done in Schools

Many headmasters and education authorities have already accepted as a fact the necessity to introduce some sort of computer studies or computer appreciation into schools. Any voices that are raised in protest are already too late. The following list gives the names of some of the places where work of this sort is going on in Britain:-

1. Royal Liberty School, Romford. This is a secondary modern school which has its own computer. The teacher in charge of the computer, W.H. Broderick, has written a book called "The Computer in School" (3). He says: "There is clearly in the teaching profession the same resistance to change that we find elsewhere." In the book, one of the topics he discusses is the educational advantages of computer programming as a discipline. The Times Educational Supplement review of 7th February, 1969, says: "At a time when computer-assisted instruction is one of the spearheads of technology applied to education . . . a book

such as this one needs careful consideration."

2. Dover Grammar School for Boys.

3. Oundle School. This is a public school for boys where computer studies has been offered to senior boys for some years.

4. The Grammar Technical School at Spennymoor. Here computer programming is taught to all Form 6 pupils. There are some other computer activities in out-of-school hours.

5. South Shields Grammar Technical School.

6. Towyn School, Merioneth. This is a small rural comprehensive school of four hundred and sixty boys and girls.

7. Leith Academy, Holy Cross, Royal High School (all Edinburgh) have all done some computer studies.

8. Daniel Stewart's College in Edinburgh has worked with a computer language called POP-2. They have had out-of-school classes for the first and second year, and also courses for Form 6. These have now been developed further.

9. In the Midlands there has been the Warley Computer Experiment. A syllabus has been devised for a five-year course, starting in Form 1. For instance, it was planned that during the first year in secondary school the children should have a series of ten forty-minute lessons. The first experiment was carried out at Holly Lodge Grammar School in Smethwick, and the City and Guilds Mnemonic Code was used:

Lessons 1 and 2: Consideration of a computer as a metal box which can do nothing without instructions. Input and output. The nature of a store. The

idea of a computer language.
A sample program using the following instructions:

RNT	Read from tape.
PNTn,m	Punch a number in the accumulator on to tape, with n digits before and m digits after the decimal point.
ADDn	Add the number in location n to the accumulator.
SUBn	Subtract.
MLTn	Multiply.
DIVn	Divide.
STAn	Store the number in the accumulator in location n.
JSTn	Jump to instruction in location n and stop.

Lessons 3 and 4: The concept of a stored program and the careful preparation of a program written on program sheets.

Lessons 5 and 6: Two further instructions.

Lessons 7 and 8: The preparation of more simple programs.

Lessons 9 and 10: Visits to the Warley College of Technology.

In the second year, the children will be introduced to loops and to the computer's ability to repeat instructions over and over again. Also they will meet integers and real numbers. The third year will extend the concept of loops and include the solution of problems by iteration. In the fourth and fifth years Algol or Fortran will be taught. The scheme is intended for all children in grammar and technical schools, and all those in secondary modern schools who can profit from it. At the moment it has been used in first-year classes only but both the teachers and the children seem enthusiastic, and some of the enthusiasm has already spilled over into other related subjects.

10. It is anticipated that equipment for computer education will soon be available to schools all over Scotland. This year, it

is reported, two firms are offering their services to Edinburgh and Glasgow schools. Systemshare is based in Edinburgh and is offering education and industry the use of £400,000 worth of equipment through 100 terminals. G.E.I.S., an American firm, is offering a similar system to Glasgow. It will be possible for a school to hire equipment; or a peripatetic teacher may travel round, taking one or two terminals with him. Ultimately, more permanent arrangements will be made. G.P.O. telephone lines are being used at the moment and ordinary telephone rates are being charged. It is expected that costs will be £5-£6 per hour for computer time and £500 for a terminal, or £33 per month for hire. The language will be BASIC, which is a conversational language like POP-2.

11. Already the examining bodies, such as City and Guilds, have syllabuses in computer science. There is A-level in the Associated Examining Board Syllabus and that of the Oxford Local Examinations Syndicate. A.E.B. is also considering an examination at O-level.

The details given above are only representative of the great interest shown in many areas of Britain over the last few years. Abroad, there is also enthusiasm for the introduction of computer studies into schools. Here are two examples:

1. At Santa Monica in California, Junior High School students since 1965 have had summer courses in computer education. They have

used a teletype terminal and a self-instruction manual. The language used is TINT (coming from "teletype interpreter") which has special error-correcting facilities.

2. In Australia, Mr. L.G. Whitehouse of Monash University has introduced computer programming and computer appreciation courses to schools in Victoria. He has devised a suitable programming language called MINITRAN which has the following instructions:-

```
GO TO
GO TO (     )
IF (     )
DO
CONTINUE
READ,
PRINT,
STOP
END
```

These instructions, also the statements DIMENSION, PROGRAM and EXTEND, are fitted on to prepunched cards. The students can write simple programs in this language and punch them out on to the cards by using an ordinary paper clip. He reckons that the charge to schools for stationery and the processing of the programs is about 10c. (1s.) per program. There is a lot of interest in the scheme he has devised, and training sessions have been arranged for teachers.

§2.3: The "Computers and the Schools" Committee

Mr. B.T. Bellis, headmaster of Daniel Stewart's College in Edinburgh, is the chairman of a committee set up by the Consultative Committee on the Curriculum. It has published a report called "Computers and the Schools" (4). "Some basic instruction in computer studies is of such vital importance to the nation and to the pupils themselves that it must be found a place as an essential part of general education," writes the Times Educational Supplement.

The committee which prepared the report was set up as far back as the summer of 1967, and its terms of reference were "to consider the implications of computers for the schools and to make recommendations". The membership of the committee includes school teachers with some experience in computer education, people from University computer departments, people representing further education, commerce, industry, and inspectors.

The committee saw the impact of computers on the world of education in three main areas:-

(a) computer education;

(b) computer-assisted instruction in school subjects;

(c) the use of computers in school administration.

The report concerns itself almost entirely with the first of these.

The members of the committee noted that already the demands of the computer aid are being reflected to some extent by the changes in the secondary school curriculum. At 'O'-level, for instance, school children are often introduced to flow charts, binary arithmetic and set notation. In Scotland, the syllabus in Mathematics for the Certificate of Sixth Year Studies includes some mention of computer programming.

The committee goes on to commend the inclusion of computer studies in the school syllabus. The computer, the report says, can be considered as an extension of the human with great storage abilities. It depends entirely on human intelligence for its operation. The discipline needed by a human being to think systematically and communicate clearly with a computer is very beneficial in itself.

But also, as computers are introduced into more and more areas of human life, men and women will be affected by them to an extent not yet dreamed of. Some young people will grow up to work with them, and certainly everyone in the future will be affected by computers in some way or other. "We cannot escape the conclusion," says the report, "that some knowledge of it should be given to every school pupil as part of a general education for modern living."

This means that children should be given not just a smattering of programming techniques, but should also have some appreciation of the capabilities of a computer and a real interest in the type of work it can do.

The teaching of computer subjects has in the past been undertaken almost entirely by teachers of science and mathematics subjects. But it must be recognised that a mathematical background is not a necessary preliminary to computer studies. The training of teachers need not be lengthy. The report suggests that a week is sufficient time to learn the essentials of a high-level computer language. However, some extended period is required for practical experience in programming. This cannot be provided by computers which are already busily engaged in industry. So local education authorities are recommended to consider carefully the siting and the installation of a computer for specifically educational purposes.

Courses for teachers are becoming more popular, and are often over-subscribed. For instance in April 1968 a course for fifty teachers was arranged with the co-operation of Moray House College of Education, the University of Edinburgh, Heriot-Watt University, Alison House and the Bank of Scotland, who provided the computer time.

The committee recommends the inclusion of an introductory course, standing in its own right. It is suggested that this might be included in the second, third or fourth year of secondary school, and should be available to all the children, not only a selective stream. This course may develop later, so that an Ordinary grade or Ordinary level qualification can be given at the end of it.

Schools will need access to some sort of computer installation. If they do not have access to a computer, it will be difficult to maintain interest at a high level. Such access may be provided by (i) the school having its own computer; (ii) the education authority setting up some sort of computer centre; or (iii) the school being given permission to use time on a computer already functioning in some other sphere. It is unlikely that many schools will be able to own their own computer. If they do, it is not likely to be a very modern one, and the facilities it offers will not in the near future be of sufficient power to be a great deal of use. If it can be arranged for a school to share computer time with a local firm or business, this may be a temporary solution. But the school must be given a fair share of the computer time; access to the computer for visits must be allowed; and the pupils should also have a chance to use the punching equipment and anything else necessary. It is best if an education authority can set up a computer centre. The accommodation required would consist of a computer room, a lecture room with a projector, and a small office. There should be at least three full-time staff, comprising a lecturer, an operator, a secretary; and there should also be two part-time punch operators. It would be useless to instal a computer system with inadequate facilities: both tape and card input and output should be available, and a line printer. This should be considered an absolute minimum. At the present, multi-access and time-sharing computer systems with telelinks are attractive but they are still more expensive, and are possibly not to be recommended until developments have become more definitive.

The report gives the outline of a suggested Introductory Course covering at least seventy periods. It suggests the following ten topics:-

		Periods
1.	Why do we need computers?	6
2.	The main components of a computer	4
3.	The applications of computers	4

4./

		Period
4.	Simple input and output media and devices	6
5.	How the computer manipulates the information	10
6.	Input, output and storage devices	2
7.	Demonstration program	4
8.	Introduction to a high-level language	20 at least
9.	Development of devices to improve information processing	10
10.	Personnel associated with a computer	4

The report finishes by discussing the languages available for use today, but does not recommend any one in particular.

The examples above and this report show that there is a great deal of interest in schools in computer studies. Some schools still hesitate, and wonder if their work is to give vocational training of this sort. It is early yet to decide how much understanding is needed by ordinary people of the processes of computing or how much time in school should be given to a consideration of the cultural aspects of a computer. But whether they are welcome or not, these subjects cannot be ignored today.

§ 3: CRISIS IN EDUCATION

The word "education" is wrapped up in layers of emotional overtones. It is surrounded by an aura of sanctity, and seems to be attached to all that is noblest and finest in our history. It conjures up an image of benevolent old age pouring out the distilled wisdom of the ages into the innocent and receptive ears of bright-eyed, eager-faced children. The petty reality of our school-days may not, in fact, have been worthy of the grand word "education"; but this truth has not dimmed present hopes for the children of today. We assume that generations of adults have accumulated a philosophy and a sense of values worth passing on to the next generation. This grave and important task, the transmission of the culture, knowledge and virtues of the race, is largely entrusted to the teachers who themselves undergo a long period of training, and who are then expected to lead a peerless life, earn the respect of their charges and the community as a whole, and devote themselves to the task of passing on the pearls of past ages to the leaders of tomorrow.

In theory and in imagination it is all rather grandiose. In fact, education, like many another sphere of human relationships, is undergoing a crisis. The key to an understanding of the situation lies, perhaps, in that word "relationship". At the foundation of the educational process there has always been a relationship between persons.

To a large extent, the quality of the education and the instruction given has depended upon the quality of this relationship. Cox and Dyson, in their "Black Paper on Education" published in 1969 (5), bring this question up to date for us in this country. They claim that by the use of modern techniques, the factory methods of mass production, and the "vulgarisation" of education, this basic relationship and hence the whole foundation of true education is being endangered. Is education an art, or is it a scientific technique? They would probably claim that it is the former; on the other hand, many people today would claim that to safeguard our society in this industrial and scientific age it must increasingly become the latter. Nevertheless, to everyone it must be becoming clear that relationships are being strained to the limit.

§ 3.1: The Population Explosion and the Demand for Education

First, the world is facing a population explosion. The increase in population means that there are more and more children and young people in schools, and unless there is a corresponding increase in the numbers of people entering the teaching profession there will be difficulties. The situation may be satisfactory just now in Britain, but it is obviously not in many huge areas of the world. In some places there is only a small number of educated adults, and these few have growing problems of administration and expanding economies to deal with, as well as the problem of educational expansion and the increasing demand by all sections of the community for more instruction in all sorts of fields.

But even in Britain there is a move today to get children into school earlier, and to continue their full-time and formal education longer. The Crowther Report confirms the fact that children, especially those from deprived backgrounds and only children, need the stimulus of nursery education from the age of three or four years. The minimum school-leaving age is to be sixteen, and young people are to be encouraged to stay on in full-time education until the age of eighteen years. For various reasons, then, the total school population is increasing. Moreover, in these egalitarian days, few people have an income which allows them to employ tutors or governesses for their children, and private schools with their small classes and high expenses are having a hard time to survive at all. The opportunity, then, for "individualised" education, from these points of view, is diminishing rapidly. Of course, it is true that education authorities try to make special provision for some children, for example, the physically handicapped and the maladjusted children; and it is also true that the various methods of group teaching, team teaching, or vertical streaming are being encouraged in order to offset the trend towards uniformity; and it is true that teachers and education students are recommended to follow a sociological approach to their pupils and to build up a complete social, environmental and intellectual profile of them. These trends show that educational planners and teachers are not unaware of the danger we are in of losing the basis of personal relationships which is so important in education, and they are trying to safeguard the benefits of individualised teaching for every child.

At the same time, however, teachers are being overloaded with supervisory and clerical duties, requirements to keep up-to-date with new methods, like the Nuffield Schemes, and with teachers' guides. Few teachers can fulfil all that is demanded of them today and still live a full and stimulating life of their own. Because they cannot, however, and because in many ways they feel frustrated and dissatisfied, they find it even harder to build up the personal relationships with their pupils and students which have been an important element in the best education and which in the past has earned their profession high respect.

Again, there is a vast increase in leisure, and there is likely to be even more. People are now able to spread their interests more widely, and they are keen to find out about subjects previously closed to them. There is a new interest in travel, and in languages, and in practical activities, and a demand by adults for instruction in a variety of fields. It is right that this should be provided, but the problems of doing so are great since so many people are starting off on their studies from different points, and have different backgrounds, and different ends in view.

S 3.2: The Knowledge Explosion

Secondly, the world is facing a knowledge explosion. Since 1900, it is said, the volume of knowledge has doubled every ten years; since 1940 it has doubled every five years. The curriculum in schools and universities is becoming overcrowded. People are forced to become specialists earlier, or they find it impossible to master their subject before it has changed beyond recognition. Adults in mid-career are having to go back and study and to tackle subjects unknown when they were in school. Teachers are teaching subjects as new to them as to the children. A great deal of new technical knowledge is needed by all sorts of people to improve industrial production today. Publishers are churning out a torrent of new books, and at best it is possible to keep abreast of only a very small part of this great flood of information.

The overall result of the population explosion and the knowledge explosion is that the educational system is creaking at the joints.

§ 3.3: Is a Teacher Necessary?

It is not, however, that the methods of education have remained entirely static through the centuries. At first, perhaps, instruction may have been entirely individual and oral. For instance, the father would say to his son, "Watch me shoot this arrow!" But as life became more complex, even teachers had recourse to tools. They took to writing on slates or tablets; they recorded things which they found difficult to remember; they used pictures. Kenneth Richmond, in his book on "Teachers and Machines" (6), points out that in the use of tools there is both a mechanical and a psychological advantage. Tools give men the feeling of mastery in a situation. By allowing them to attack a problem from another angle or level, or by another means, or with greater resources, they prove that men are capable of transcending their physical limitations. Books, especially printed books, have always been a student's most useful educational tool. They have freed the student from utter reliance for information on another human being. A student, it is true, may be inspired by a brilliant teacher; but he may just as easily be misled or dulled by an incompetent one. The wise use of books, however, can largely make up for the deficiencies of a teacher.

From time to time, even in past centuries, various types of mechanical apparatus have also been used in teaching, but their use has not weakened the basic conviction that there really is no adequate substitute for the sort of personal tuition given by a private tutor to the sons of the aristocracy. It is this ideal that has been reached for, even by those who have democratised education, and there has always been a strong reluctance to depersonalise instruction and use mechanical devices. Professor M.V.C. Jeffrey has a comment here. He says: "It is a mistake to regard craftsmanship as incompatible with machinery; from the first axe to the electronic computer is only a matter of degree. But craftsmanship is incompatible with such division of labour as deprives a task of meaning." Behind this fear of the use of machinery for teaching purposes is perhaps the fear that men, passing through the same mould, will all turn out in the end of the process to be just copies of each other. Men, it is feared, will, by this very process, cease to be men; they will abnegate their very nature and the essence of their humanity. The Greeks sought for arete or "excellence" in all things. We are afraid today that men, moulded, if not subjugated by machines, will lose their own essential humanity. Surely it is this fear which makes people cling on to the idea that the one necessary element in education is a human teacher. But the crisis in education is forcing a new question upon us: in education, is a teacher, in fact, really necessary?

§ 3.4: The Mechanisation of Education

The whole process which is called "education", and which occupies the first fifteen or twenty years of a person's life, is a collection of many influences and processes; likewise, there is not a single aim of education, but many. For instance, some of the aims of education are:-

creative thinking;
development of acceptable attitudes;
socialising of the child;
physical development;
development of skills and techniques;
acquisition of factual knowledge.

The influences that contribute to the process of education are also mahy. There is the influence of home and family; the contribution of classmates, the libraries, the physical environment, the cultural and recreational activities of society, as well as the activity periods, and periods of intellectual study in various groups at school. The introduction of educational technology cannot bring about the depersonalisation of all these other influences.

To some extent, the exact opposite is the case. Teachers today are under pressure. Besides the load of assessments, marking, record-keeping, and the need to keep up to date with advances in their own field, teachers are urged to use individual and group methods with their children, and to give personal encouragement. It is almost too much. Most frequently, the aspect which is squeezed out is the last. It would seem that the introduction of more educational technology into the work of the schools would free teachers from much that is mechanical and repetitive and enable them to give more attention to the tutoring of individual children.

Education is not the only field which in recent years has been faced with a crisis. Many enterprises in government, industry, medicine, transport, administration, have been faced with similar problems. In almost every field, the planners have accepted the introduction of new methods. Great sums of money and great amounts of energy have been spent on the introduction of new enterprises. Education by comparison has been slow and most teachers have remained relatively untouched by the revolution going on around them. This is hardly the way to fit children for life in the modern world. Now it seems that the population explosion and the knowledge explosion are forcing us to reconsider our methods, and in the computer we have a tool which can help us to make a big change from tradition.

§4: PROGRAMMED LEARNING

§4.1: Pressey

In spite of the conservative attitudes of most teachers, there have always been some innovators and experimenters. Early in this century, Sir John Adams had seen how education might be developed. In 1912 he said, "In the Aristotelian sense, to be sure, education is a practical science." In 1926, Sidney Pressey, in Ohio, made a contribution to the publication "School and Society," outlining new methods of teaching. In 1934 one of Pressey's colleagues, Dr. J.K. Little, wrote an article for the Journal of Experimental Education in which he claimed he spent an average of one thousand hours per year on marking. About the same time, they undertook a series of experiments in teaching. First, there was a sort of typewriter which counted the number of correct responses tapped out on it. Next, there came a machine which would not continue with its program until the correct response to the last part was given; and this also counted the number of incorrect efforts made before the correct response was given. At this time, Little was giving his students twice-weekly tests of thirty questions with a choice of answers, true or false. If a student made a wrong response, he could go back to the beginning, start again and still get a mark of 100%. The students using these tests had better examination results than the others. In spite of evidence of the usefulness of Pressey's methods, manufacturers and publishers were not interested, and even by 1932 Pressey had been becoming discouraged. In "School and Society" of 19th November, 1932, he wrote an article called "A Third and Fourth Contribution toward the Coming Revolution in Education." He said:-

> Education is a large-scale industry; it should use quantity production methods. This does not mean, in any unfortunate sense, the mechanization of education. It does mean freeing the teacher from the drudgeries of her work so that she may do more real teaching, giving to the pupil more adequate guidance in his leaning. There may well be an "industrial revolution" in education. The ultimate results should be highly beneficial. Perhaps only by such means can universal education be made effective.

§4.2: Skinner

In 1954 there appeared another American to champion the cause which Pressey had long since abandoned. "Marking a set of papers in arithmetic - 'Yes, 9 and 6 are 15, 9 and 7 are not 18' - is beneath the dignity of any intelligent individual. There is more important work to be done, in which the teacher's relations to the pupil cannot be duplicated by a mechanical device." So wrote B.F. Skinner in an article in the Harvard Educational Review of 1954. He had been doing experimental work with pigeons, teaching them certain desirable responses. He decided that nothing succeeds like success, and that an important factor in the learning process is the reinforcement of responses. Once the desired terminal behaviour is achieved, such as turning in a circle in a clockwise direction, or going through a whole series of manœuvres, then only intermittent doses of reinforcement are needed. This process of reinforcement he called Operant Conditioning. This process could, he felt, be applied to many learning situations. In the formulation of a learning program, the first task is to determine the desired terminal behaviour. In doing this, an assessment must be made of the skills and information already possessed, those which the subject is expected to acquire, the order of acquiring them, and the small interlocking steps by which he is to acquire them. In the training of pigeons, the desired behaviour was rewarded, or reinforced, as soon as the least move in the right direction was shown. At first, of course, this was naturally a chance move, but after the first time it was at least partly motivated. Immediate and inevitable rewards were necessary.

In an ordinary school situation the reward, as often as not, is the mere satisfaction of getting the right answers. To ensure this satisfaction there must be a maximum error rate of 5%. There must also be an active response on the part of the pupil; and immediate correction if the response is wrong; and cues and prompts to help him if he is uncertain. These principles were embodied in mechanical devices known as Skinner boxes. Skinner boxes were at first cheat-proof, and they were a tremendous success. In 1958 a certain article was selling for eighty dollars, and three years later production had increased to such an extent that essentially the same article was being mass-produced for six dollars. "We are on the threshold of an exciting and revolutionary period," wrote Skinner.

Skinner evolved five main principles for his learning programs. These he derived from the analysis of the behaviour of pigeons and other small animals observed during periods of learning.

First, there was the Principle of Small Steps. This means that the terminal activity must first be defined, and then the approach to it be broken down into small sections so that behaviour is gradually conditioned or new ideas gradually assimilated. The size of the steps is important for a pupil. If the steps are too small, he will become impatient, and will lose the overall picture, and become lost in a mass of seemingly unrelated insignificant details. If the steps are too big, he will not be able to make the jumps demanded of him, because his responses will be insufficiently conditioned. He will repeatedly make errors, and Skinner decided that a student does not learn if he frequently makes errors. It has not yet been shown how far this is true.

Secondly, there was the Principle of Active Responding. It was demonstrated that a student learns little algebra, for instance, if he merely reads the text, and reads through the explanation and the examples. The best way for a student to learn algebra is to work through some examples himself and get into the habit of facing problems and making an active response.

Thirdly, there was the Principle of Immediate Confirmation of Results. If a pigeon made the wrong movement, instantly it received its punishment, which meant usually no food; but if the response was correct, it immediately received a reward. Thus the reward is strongly connected with the desired response. If too much time elapses, this connection is not evident. Skinner came to the conclusion that children, too, needed to know immediately if their answer was correct. To wait for a couple of days, or more, while their exercises were marked and returned meant that the errors had become fixed, or else the link between the thinking process and the correct conclusion had become obscured. Recently, Professor Skinner has expanded his views on the effects of rewarding behaviour. At the First International Conference of the Association for Programmed Learning and Educational Technology, he spoke on "Motivation and the Student," and said that from earliest times students had studied to avoid the consequences of not studying. Though educationalists had not been happy with the use of punishment as the motivation to learn, the alternatives had not been very successful either. There seemed to be plenty of examples about of the reinforcement of undesirable behaviour by placating or diverting children when they misbehaved. What really was needed now was the study of motivation, and the effects of rewarding good behaviour, and the best means of encouraging right responses.

The fourth principle was the Principle of Self-Pacing. This allows for the fact that people are different and learn best if they can work at their own speed. Work must be individual. Some people will be able to rush ahead; others, if they wish, can go over a step once or twice again.

The fifth principle was the Principle of Student Testing. By this, Skinner meant that the program could and should be altered in order to carry out the teaching more efficiently in view of the results gained to date. Accurate records of the learning experience of each student would be readily available. If there were some inefficiency at one stage or another, this would be shown up by the excessively large number of errors made by students at this point. The program could then be revised until it fitted like a tailor-made garment.

There are criticisms which can be made of this method. Skinner assumes that, once the terminal behaviour has been decided, there is only one best path by which this can be achieved, and this one path is followed by the steps of his program. But bright students will find it annoying to have to work through a series of laborious small steps if the conclusion of the process has been clear to them almost from the beginning. Perhaps not enough notice has been taken of the "all or nothing" method of learning. It is a sort of immediate revelation of the whole, by which some people, possibly after a long preliminary period, suddenly grasp the essential facts of a situation.

Skinnerian programs also often lay themselves open to manipulation by cheating. Even if a student does not cheat, he can sometimes "work" through a program with very little active response. He can just look at the answer displayed in the next frame. Some teaching machines have been evolved which ensure that the correct answer is not seen until the student has made some sensible response to the question asked. A computer could be programmed to do this. On the other hand, the results of some experiments have indicated that learning can take place in spite of this type of cheating.

§4.3: Crowder

Crowder was a wartime instructor in the United States Air Force. He evolved a teaching method using cards. On these he wrote certain information, and then a question to test if the material had been learned. On the back of the card was the correct answer. Some students needed to work through all the cards; others were allowed to omit some. This was the basis of his "scrambled" books using the "intrinsic programming" method. The principles on which Crowder worked were a little different from Skinner's. He maintained that the units of material must be fairly substantial and that the student must really be made to think for himself. He did not believe, to the same extent as Skinner did, that errors discouraged learning. He allowed for more errors and different types of errors. But he offered remedial treatment immediately by the method of branching. This in itself causes many difficulties. Too much branching makes a program bulky and tedious; too much jumping about from card to card, or page to page, is wearisome unless it can be mechanized. Because it is wearisome, there is an even greater tendency to cheat if this is possible. Moreover it is a great <u>tour de force</u> to write a branching program with all its ramifications. All possible errors should be foreseen by the writer of the program; but since this is virtually impossible he must select the errors a student is most likely to make, and deal with these. This means the responses must be in the form of multi-choice answers, not constructed responses, as in the Skinnerian method. This is not entirely satisfactory because the students will be confronted with wrong answers which perhaps they would have never imageined for themselves; and possible the answer a pupil thinks is correct is not, in fact, among the choices offered, unless one choice each time is "None of these". A great deal of the remedial work offered in a branching program will in many cases not be required and these extra branches will for most people only serve to make the program unnecessarily complicated.

To get over a number of these objections, the first Mechanical Tutors were constructed. These have been modified and can now make use of various types of material. One such piece of apparatus at present on the market and highly recommended by one educational reviewer is the Tutorpak Teaching Machine. This is a compact unit which can easily be moved, weighs less than 4 lb., and measures 15 inches by 11 inches by 2 inches. It contains up to twenty foolscap sheets of instructional material, each divided into about twelve frames. The programs are easy to slip into the machine, and the machine is easy to manipulate. A feed roller knob displays the current frame and the answer to the previous frame. When one sheet is finished, the feed-knob moves that sheet into a magazine and the next sheet is engaged. When the program has been completed, the magazine containing the program can be removed. Cheating is discouraged by the fact that the feed-knob works in only one direction. Answer slips are separate from the question sheets, but they are interlocked with them. The software package consists not only of the printed programs, but also other material such as plastic models, drawing sheets and pictures, which help to extend the scope of the lesson.

This sort of program has great advantages over the original series of cards, or the first scrambled texts. A mechanical tutor has considerable storage capacity, and can make use of films, aural and visual aids. The mechanism and the lighted frame rivets the learner's attention. Many students find it satisfying to manipulate a simple machine, and find that the process is not so tedious as working through the printed pages of a text-book. A few years ago in the U.S.A., a cartoonist produced a drawing of a teaching machine which showed a mechanical device with a lid. When the lid was removed, a flesh-and-blood teacher was revealed inside the box. The artist was nearer to the truth than perhaps he knew, because ultimately, of course, the quality of the programs is dependent on the quality of the program writer. The programs are only mechanised to a certain extent, and the writer draws on his experience and his personal encounters in the classroom. In Britain, a report on programmed instruction issued in April 1963 by the Ministry of Education said: "These developments have a considerable potential, have certainly come to stay, and are likely to evolve in a wide variety of ways, some of which cannot be foreseen."

§4.4: More Recent Developments

There have been several developments in this field, and it is worth looking at some of these since the techniques, if they are good, may well be computerised in the future.

One of these is the Talking Page, produced by Rank-R.E.C. Ltd. One of the principles behind this learning machine is that the learner must be totally involved in the process, not a participant as are so many children in the classroom. The apparatus looks like a desk top, and weighs 16 lb. A specially designed and illustrated book is on top, and a disc, controlling the "audio" part of the machine, is fixed at the back. The book and the disc are coordinated, and the book is marked in sections indicating various audio access points. By moving a lever to the correct point, the child can call up the correct audio messages, and these also tell him when to turn the page. The mechanism is simple enough to be operated easily by a child of five. It is strong, and, the manufacturers hope, child-proof. It has been used in primary schools with programs in mathematics and music, but is especially recommended for first and second stage reading with immigrant children. Its special attraction seems to be its power of random access and audio presentation. Children who have used it have established good relations with the apparatus and have come to look on the Talking Page almost as a friend.

At France Hill School in Camberley, the Nuffield Resources for Learning Project has been conducting an experiment in programmed learning in mathematics, using sixty teaching machines. The school is a coeducational secondary comprehensive school, and the experiment has been taking place during the year 1968-1969. Six unstreamed classes of eleven-year-old children are involved. One class is acting as a control; in two of the others, the children use the machines in pairs and the amount of participation varies from group to group. It seems that the work done in pairs is not so successful, largely because the machines are not really big enough to allow two children to work with them simultaneously. Some machines have been lined up in the corridor, since space is short. The atmosphere among children using these is not so good as among the children in the room where the machines are grouped together. Here there has developed a pleasant informal, communal atmosphere. One report says that the atmosphere is more relaxed than in a normal class situation, and children go round freely, discussing their work. Results are at the moment entirely subjective, and these obviously do not prove any point in favour of programmed learning; but the project really is committed to showing that this sort of method is not only possible, but also can be positively successful. It has certain special beneficial characteristics, so that with large unstreamed classes it may well become more and more the pattern for future instruction.

At the Thomas Bennett School in Crawley, another experiment has been set up under the Nuffield Resources for Learning Project. The underlying belief here is that the "chalk and talk" approach usually adopted for teaching children in school is not adequate. The project is trying to find out how resources can be differently used. For instance, the director wonders if it is true that increasing the number of teachers would improve the quality of our education; or, he asks, would it be better to spend less money on teachers, more on materials, and, moreover, on materials quite different from those usually found in schools at the moment. Full participation by the children seems necessary for efficient learning, and individual learning, such as that supplied through programmed learning techniques, seems most fruitful. Four biology classes in the second year are involved in this particular experiment. One class is used as a control. When one of the other classes comes for a lesson, the children are given free access to the three laboratories and all the equipment. They follow a program which instructs them in minute detail what material they should use, and how to use it, and it also questions them on their results. For instance, use is made of film strips at certain points, and the children are expected to work the projector for themselves. There is plenty of movement, opportunity for initiative, and, inevitably, plenty of noise. But the experimental classes are three weeks in advance of the control group. Most of the children, though not all, said they preferred this method of learning to the traditional method. Many of the teachers found the situation unsatisfactory. They felt they had been deprived of their independence; they felt that the programme, not they themselves, was in charge, and that their rôle had been reduced to one of baby-minding.

They felt that their job had been reduced simply to answering questions about the whereabouts of various bits of equipment which the program had instructed the children to use.

Similar results have been obtained with older students. Navy instructors on H.M.S. Vincent used two methods for the teaching of trigonometry. Some men studied from programmed tutor-texts. Others worked through the course on teaching machines. Those using the tutor-texts did almost as well as the others in the final test, but they seemed to find the work less agreeable. Both groups took far less time to reach an acceptable standard than did a control group which was working under a teacher in the usual way.

Results obtained from this kind of work with machines, and the comments from teachers and students, are interesting to those concerned with the development of computer-assisted instruction. A computer can do all that a mechanical tutor can do, and it can do it more efficiently. If it can be shown that mechanical teaching machines have a place in our teaching system, those who are experimenting with computer-assisted instruction will feel all the more encouraged to continue with experiments in their field.

§5: EDUCATIONAL THEORY

§5.1: Internalist and Externalist Theories

The ideas fundamental to the production of teaching machines are based on sound educational theories, developed over a long period of time. In recent years there have been two strands in educational thinking about learning which can be generally described as "the externalist theory" and "the internalist theory". Locke was a proponent of the first, and he felt that environmental influences were all-important. He considered the learner to be "white paper, void of all characters". Likewise, the Herbartian doctrine is that it is the teacher's job to INSTRUCT, while the children remain inactive recipients of the instruction. On the other hand, the internalists, like Comenius, Rousseau, Pestalozzi, Froebel and Dewey, maintain that the dynamics of learning are to be found within the learner himself. The teacher's job, according to them, is to EVOKE. From these main ideas, the following differences can be derived:-

	Externalist Theory	Internalist Theory
1.	The learning process is the acquisition of knowledge, and the furnishing of the mind with ideas.	The learning process is the acquisition of experience, and is a process of gradual accretion.
2.	The requirements of adult life and society ought to determine the aim of education.	The pupils' present needs and interests should provide the starting-point for their education.
3.	Education must use logical methods.	Education must use psychological methods.

4./

4. Methods should involve intellectual training.	All-round development of the person is the most important result to be sought.
5. Freedom comes after discipline and success.	Freedom is a natural right from the start.
6. Pupils must accept external authority.	An appeal to authority is often unnecessary, and repressive.
7. The teacher must be firmly in control at all points.	There should be pupil participation whenever possible.
8. There is an assumption that interest follows on from effort.	There is the assumption that effort results from interest.
9. Work comes first and play comes afterwards.	Work and play can be combined.
10. Good order in school organisation is necessary, e.g. well-arranged desks, a fixed time-table, streamed classes.	School organisation can be informal, e.g. moveable furniture, a fluid timetable, and group-work methods.
11. Curricular and extra-curricular activities are kept quite separate.	There is no such distinction.
12. Stress is laid on the importance of formal instruction.	Learning by doing rather than by listening is the method to be used.
13. The basis is a speculative psychology grounded in a moral philosophy.	The basis is experimental psychology based on behaviourism.

There have been these two streams of thought in education in this century. Dewey too has had a great influence in educational thinking. According to Dewey, a pupil first senses a difficulty or problem. Then the next step is one of exploration; he searches round the problem. After this experience, he is in a position to suggest a solution. The implications of his suggestion are followed through, and some sort of general "theory of approach" is reached. Finally, this theory is tested out in a variety of similar situations. Pestalozzi, also, said that there could be "no impression without expression".

It is interesting to note that in all these theories of education there are some elements which fit in well with the programmed learning approach. Programmed learning, in fact, combines some of the best of both the child-centred and the teacher-centred methods. Z.K. Dienes, a living mathematician, educationist and psychologist, clearly sees these two elements. He says:-

> Mathematical thinking, like any other kind of creative thinking, has no predetermined end and cannot be completely mechanised. This does not mean that certain phases cannot be standardised to become quite mechanical. If we are climbing up a mountain, a rock-climb may be necessary as part of the ascent; and then our awareness of the detailed activity must be considerably higher than during a walk up the "standard" road. Just as we must be aware of every foothold during our rock-climb, so we should not shrink from employing an even greater degree of mechanisation on standard stretches, such as taking a train, bus or plane. This is perhaps the best method to adopt to the introduction of teaching machines.

§ 5.2: Methods of Learning

It is interesting to consider various ways in which we learn, and to ask ourselves if mechanised methods of teaching can make use of these different ways, or not. Perhaps the main ways in which we learn can be divided into these four groups:-

(a) trial and error methods;

(b) imitation;

(c) practice and training;

(d) insight.

(a) Trial and error methods are certainly used in programmed learning; in fact, "branching" is the technique employed to deal with the various errors caused by erroneous trials. Skinner feels that there should be only a small error rate; between five and ten per cent. He thinks of errors as punishers, and thinks that learning is more efficiently achieved through a system of rewards, i.e. the satisfaction gained from the knowledge that the question has been correctly answered. In fact, he doubts if learning can take place at all if the error rate is inordinately high. There is, however, a difference of opinion on the effect of errors. G.O.M. Leith declares: "Pupils have learned when the error rate is high, and failed to learn when it is low." Pressey wrote: "Wrong answers need not be like blind alleys in a rat-maze, but, instead, clues helping to delimit an area." Kenneth Richmond, however, thinks that there is a fair amount of truth in the assertion "that one of the paradoxes of the British system of education is that it is geared to failure". Other writers maintain that selection procedures, depending largely on trial and error methods and ensuring a high failure rate, can only produce feelings of humiliation and despair in the children. I.K. Davies agrees that the overall efficiency of teachers in this decade is about twelve and a half per cent - "slightly greater than that of a steam roller." It is true that linear programs try to ensure a low error rate by the use of cues and prompts and a great deal of repetition, but this may, in fact, be annoying to some students. Computer-assisted instruction and programs relying on branching techniques accept the possibility of a high error rate; but they provide for this by allowing a return to earlier frames and by the inclusion of a great maze of remedial and repetitive and explanatory branches. It is not really clear which techniques are the best, nor for which types of student, and there is a great deal of work still to be done on the effect of errors on learning.

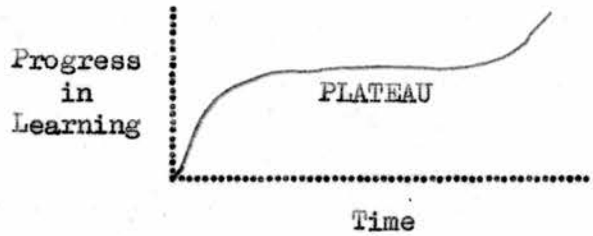
During the last few years, however, "discovery" methods have been very fashionable and these can be considered as belonging to "trial and error" methods. It is true that what a child discovers for himself he knows in no uncertain manner. But the use of the discovery method does imply the making of a great number of errors and often a great number of abortive attempts to find a solution. To avoid this wastage, the way can be prepared by the teacher, and hints can be given. If this is the case, this method approaches more nearly to "trial and error" than "discovery". It is difficult to see how this method can otherwise be used in programmed learning or computer-assisted instruction. By definition, true discovery is the very opposite of "learning by program", because one cannot, in fact, program for something which has not yet been discovered, not knowing even how the discovery can be made. True discovery method is almost the same as the insight method. For these reasons, in school the true discovery method has its limitations; it is more suitable for certain children under certain, and often unpredictable, circumstances. Some teachers, moreover, feel that the basic idea behind the concept of progress means that children do not need to go back and "discover" for themselves all that past generations have already discovered. Progress does not consist of making errors that have been proved to be errors, nor of making discoveries that have already been made.

A modified form of the discovery method, more on the lines of activity methods, or learning through personal experiment or experience, is possible with programmed learning. This means, probably, making use of a variety of materials, and using the program merely for preliminary explanations and instructions, and then assessing results and testing the validity of conclusions reached. This type of work has not been tried out to any great extent with computer-assisted instruction.

(b). Children learn a great deal through imitation. Aristotle thought that one of man's greatest assets was his ability to imitate. Wordsworth described imitation as "the child's whole vocation". It may be that in these modern days imitation has been too much despised. But perhaps it is not as sterile as people have been led to believe. It is not necessarily the arch-enemy of self-expression and creativity (if these are our ideals today), for at the time of the Renaissance the artists and writers were certainly filled with a desire to imitate the great productions of an earlier age, but the overall result was a period when the flowering of the creative human spirit was at its height.

The element of imitation is one which can easily be used in programmed learning and computer-assisted instruction. It is this which lies behind the idea of cues and prompts very often in linear programs. Answers produced by imitation can be checked fairly easily by computer methods, since the field of possible answers is usually well defined.

(c) After a fact has been taught or a method has been established, children often require long or short periods of <u>practice and training</u>. This is a period of consolidation; very little progress is to be seen at this time which is often referred to as the plateau in the learning process.



It is this plateau period which teachers can find so wearisome in an ordinary school situation. Each child, for example, in the learning of the multiplication tables, needs so much individual practice. In the ordinary multiplication tables which it has been customary for school-children to learn there are one hundred and fifty-six facts (including zero facts, such as $0 \times 1 = 0$). If there are forty children in the class, and the teacher were to test each child orally on each fact only once, over six thousand questions would be necessary. Usually, of course, a child would need repeated questions before a fact was firmly established. This is an impossible situation, and no teacher is capable of undertaking such a task. As a result, some children learn more slowly than need be the case; other children just never learn some of the basic facts. Each child, in all his work at school, starts off from a different point; each one finds different things difficult. In such situations, the use of the class teaching method is extremely inefficient. It brings inordinate pressure on the teacher. And this is the point where programmed learning, by being individualised, can help a great deal. Computer-assisted instruction is particularly suited for "drill and practice" techniques because the computer is capable of virtually endless repetition. It is tireless and uncritical, and it does not get emotionally involved. It offers great facilities for practice, and because of this very fact, there is a danger of thinking that no other methods are suitable for computer-assisted instruction. It has yet to be established how much practice really is beneficial in a learning situation. Today many teachers feel that practice is needed only until a principle is established. Thereafter, some think, practice is relatively unproductive. This has resulted in the tendency today to reduce the number of arithmetic periods, for example, in school, and also the number of examples and exercises to be worked through in arithmetic or algebra textbooks. Nevertheless, this is the sort of work which could be taken over by computers. Teachers could then be relieved of a great deal of oral work and marking which most of them find particularly tedious.

(d) Psychologists know less probably about learning by <u>insight</u>. in recent years, a great mass of information has been gathered on the subject of learning and some of its constituent parts, and to some extent the study has been an example of losing sight of the wood for the mass of trees. When all has been diagnosed and dissected, there is still something essential which eludes psychologists. When all has been analysed, imitated, practised, drilled, there is still something more. In fact, this idea can be taken one step further: if a subject is analysed and dissected and drilled, something is often lost in the process. Pestalozzi's concept of "Ausschauung" illustrates this. He demonstrates not only the need of the learner to proceed in small steps, but also his need to see occasionally the whole subject at one glance. Programming is the breaking down of a subject into very small steps, and the optimum size of these steps varies from person to person. A programmer must always aim to make these steps so clear that the direction and the outline is not lost. Nevertheless, the steps, one after the other, must take the learner in one direction only. He is not allowed to find his own path from one point to the next; and if he gets a view of the whole subject as he proceeds, it can only be the view which the programmer had when he planned the path and the steps.

All of this takes no cognisance of another method of learning which, by its nature, is very difficult to investigate: the "all or nothing" method. Some people, it seems, are able to take, perhaps by instinct, a leap in the dark and land safely in the right place. If they are able to make dramatic advances in their learning like this, they will only be bored by being forced to follow the inevitable path through a programme, branching or linear, unless it is well constructed with their particular needs in mind.

What are the conditions under which this type of learning takes place? Can a program writer, by the judicious use of branching ahead, as well as back, make use of the ability which some people seem to possess to learn, as it were, by instinct? These are ideas which remain to be fully investigated. It is true that educators continually underestimate the ability of some if not of most of the children they teach. Many children are capable of much faster advance along these lines than at the moment they seem to be given credit for in school or indeed opportunity. Outside the classroom, when faced by a welter of news and information in newspapers and magazines and on the radio and television, children show amazing powers of memory, assimilation and understanding. There is no preparatory work, no programming, no post-testing. Their learning seems to be by instinct, and it seems that there should be more opportunity for this method to be used in school. It is yet to be seen how computer-assisted instruction can use this faculty.

§5.3: Advantages and Disadvantages of Programming Techniques

Teaching by program - whether it be in book form or in the form of computer-assisted instruction - offers some advantages not found in an ordinary classroom situation. In this method, a student is not so completely dependent at the time of learning on his teacher, as he is in class-teaching; nor is he dependent on his fellow-students, as he is to some extent in group teaching. These facts have various results. There may develop in students who learn by program qualities of independence, self-discipline, self-motivation. They do not have to wait for other people before they can begin. They are not called to stop because others are stopping. Each one is in competition with himself rather than with other people. It is true that these factors may lead to over-independence; but it is not envisaged that all a pupil's learning will be by means of programs, or computer. Another advantage for poor pupils is that they will not be embarrassed in public by their inability to give correct and speedy answers to questions which other children find easy; and there is no public disapproval meted out to them if they ask for a repetition or an explanation.

There are also disadvantages is this system of teaching. Both linear and branching programs, and all mechanical devices, do allow pupils to work at their own pace, but they do not really have the capacity for allowing a pupil to work at his own level. B.N. Lewis, in "The Rational of Adaptive Teaching Machines," points out that human beings have a "tendency to withdraw (through boredom) from tasks that are too easy, and to withdraw (through frustration) from tasks that are too difficult." From time to time, it is a good thing to touch the upper limits of difficulty, though pupils are known, all too frequently, to protest at this painful stretching of their latent powers. If a pupil can be stretched and can reach the upper limit, he may consequently be spurred on to greater efforts through his previous success. If he fails in this effort, often weaknesses are shown up under a certain amount of stress which would not have revealed themselves had circumstances been easier. For each person, there is an optimum level of difficulty, and on both sides of this optimum there is only a narrow region which can hold the pupil's full interest. In teaching, it is important to keep the work somewhere in this narrow region for each person, touching the upper limits from time to time. The effect of this theory is almost to suggest that each individual needs his own personal programme of study. In fact, it appears that the task of the program writer gets more difficult, the closer it is studied, and one wonders if, after all, it is only a computer that can cope adequately with all the variables in the situation.

Programmed learning, then, has been accepted hesitantly. A great deal of work, especially in the U.S.A., has gone into the development of hardware and the writing of programs. But Mr. Christopher Gane, director of the Centre for Research into Educational Technology, speaking at the Brighton Computer-Assisted Instruction Conference in 1968, said that he thought it would be futile and expensive to introduce computer-assisted instruction into British education. On the other side there was Professor Brian Thwaites, now Principal of Westfield College, University of London, and formerly Director of the Schools Mathematics Project. He said: "We must look forward to ten or twenty years from the first wave of the new mathematics." The mathematical curriculum, he said, should be based explicitly on computers. "We have to plan for 1988 when there is a computer in every classroom." Another voice comes from the U.S.A. Patrick Suppes has worked for several years as Professor of Philosophy and Statistics, and as the Director of the Institute for Mathematical Studies in the Social Sciences at Stanford University. One of his comments is this: "The truly revolutionary function of computers in education . . . lies in the novel area of computer-assisted instruction." Other voices are being raised in support of this opinion. Organisations and individuals, certain that children are capable of learning far more and far better than they do at the moment, and aware that it is important today that they do so, are setting out to experiment in this new field of education.

Pressey has been able to look back over a quarter of a century of rather slow development. Writing in 1959 in an article produced for "Automatic Teaching," he pointed out that from a practical point of view, in most branches of applied science it was not enough that a new method could be seen to work well. Before a changeover is really feasible, before people are really prepared to welcome and to put into practice new ideas, these ideas must be seen to work not only better, but very much better, than the usual methods; and they must do so not only in special situations where conditions are well under control, but also in ordinary situations where average people are in charge and have no vested interest in demonstrating the unfounded success of the new ideas. Programmed learning, though it has recorded a certain amount of success, has not so far been able to make this overwhelming impact. It seems still to be waiting for some new break-through before it is wholeheartedly welcomed by the teaching world.

§6: COMPUTER-ASSISTED INSTRUCTION

§6.1: Computer Facilities

It does seem that the introduction of a computer into the field of programmed learning could constitute the break-through which is needed. It can provide many of the facilities of a programmed text, and more besides.

(a) Instruction can be adapted to the individual learner. In theory, this should be easier with a computer than with a programmed text. Adaptation to the individual in this way implies adaptation along several lines:

(i) The instruction can be adapted to the rate of learning. With remote consoles working on a time-sharing basis, there is no reason why a pupil cannot go as slowly or as fast as he likes. He is not wasting computer time if he spends a long time working on his problems.

(ii) A computer can be programmed to adapt the work as it progresses. It can keep a record of the responses of the pupil and it can be constantly assessing these, and timing the work done. When certain limits of time or errors are reached, it can automatically jump to another branch, or print out suitably helpful comments.

(iii) The instruction can be adapted to the personality of the learner. Some students perform better when faced with a stiff challenge. Others wilt when confronted by a task that is too difficult. Some students who ask for help are completely non-plussed if they are told to go away and think for themselves, while others respond to brutal treatment. Some students are quite inhibited by comments such as, "You really are a silly ass!" Others, in similar circumstances, may find that they are not stimulated by gentle encouragement, such as, "That was quite a good effort, but it was not really the answer that was required." Personality types could be coded, and the code number could be read in with the name of the learner. The same subject matter could be dealt with in different programs, or, better still, the learner could be sent off on to different branches according to the personality code number.

(iv) Instruction could be treated on different levels. This idea is at the basis of a program devised by Ralph Grubb of the IBM Corporation in Canada. More will be said about this later, but this is an example of an attempt to plan work on different levels and cater for a person who wants a full treatment of the subject, or merely an outline of the course, or a course of some other type.

(v) The "author mode" in a system can be used whereby the program can be changed even while it is running. This facility gives computer-assisted instruction a great advantage over a programmed text or mechanical tutor. To change one of these programs after publication is a difficult and expensive business.

(b) Routine and repetitive work like drill and practice can be carried out by a computer without fatigue, without embarrassment or shame on the part of the learner, and without exhaustion or fury on the part of the teacher. It can also be done without making it too obvious to the pupil that he is standing still, to all intents and purposes, on the "plateau" of the learning process. After one "plateau" there comes another period of activity and progress, but this time can be very frustrating for the teacher and very tedious and discouraging for the learner. It is a time of consolidation for the pupil and of patience for the teacher. It is often at this time that relationships can become strained between pupil and teacher. Some pupils spend a long time on this plateau, and a programmed text can only give the practice needed at this point by constant repetition, or by going back over certain frames time and time again. A computer-assisted instruction program does not show up the lack of progress like this, but it can produce for as long or as short a time as is needed a variety of practice examples on the point being studied.

(c) The computer is tireless and dispassionate over the keeping of records. Indeed, this fact may turn out to be as much an embarrassment as a good characteristic, because the computer is capable of keeping more information than the teacher always wants. A programmed text can also provide a record of the work of the pupils in the form of their answer sheets filled in as they worked through the programmed text; some mechanical tutors can keep a count of correct answers. None of these can supply the record-keeping facilities of a computer; even if they provide the evidence, it is still left to the teacher to collate and analyse it.

(d) This amassing of information about the progress and personality of each pupil means that there will be made available for the worker in educational research far more material than he has previously had. The computer itself will be able to analyse in certain ways the material it produces. Moreover, the computer is able to provide a reproducible environment and it can control its own experiments far better than has previously been possible.

(e) A computer will therefore be able to provide more facilities for the educationist. But all of this forces the practitioner to face more squarely than before the most fundamental of all questions in education: what is all this for? what is the desired "terminal behaviour" which Skinner talked about? Is it, in fact, possible to define the "terminal behaviour" for every learning situation; and can it not be envisaged that some learning may lead to new knowledge or understanding which has not yet come to light and therefore can hardly be described as "terminal behaviour"? What is the aim of instruction anyway?

Computer-assisted instruction is likely to bring new problems as well as new facilities. Some of these are discussed below:

(a) Very young children need a natural environment for learning, and they seem to need the response and stimulus of a flesh-and-blood teacher. For some people, it may be found that the artificial mechanical environment provided by a computer is a disincentive to learning.

(b) Some subjects do not lend themselves easily to the sort of fragmentation and factual analysis which programming demands. It is not possible to say if some subjects are entirely unsuitable until a lot more work along these lines has been undertaken. Kenneth Richmond, for example, wrote a programmed text on literary appreciation to make the point that programmed learning need not necessarily be confined to mathematical and scientific subjects. It is not clear at the moment to what extent attitudes and opinions can be influenced by programmed learning methods.

(c) It is true that computer-assisted instruction courses are often too rigid. A human teacher can be very flexible, bring in new or topical material as it becomes available. This deficiency of mechanical or computerised devices, however sophisticated they may be, was illustrated in the moments before that first touch-down on the surface of the moon. The astronauts had been brought directly on course from the earth, but in those last few moments it was clear that the landing craft was heading for an area most unsuitable for their mission. They therefore, in this critical situation, cut off automatic control and took over themselves. Nothing has yet been discovered which is as flexible in a crisis as a human being.

(d) Programs, especially those suggested above which can be adapted to cater for individual personality differences, different rates and levels of working and so on, are inordinately difficult to produce. They are very expensive and time-consuming, and it may seem more economical to spend this time and money on developing education along lines which are more immediately profitable.

(e) In fact, the expense of computer-assisted instruction seems its present greatest drawback. It involves firstly big capital expenditure. Thereafter it involves the training of expert personnel, both to write the programs, to run them on the computer, and to keep both the program and the computers up to date and in running order. The cost of computer time, and of the various pieces of equipment, and of the research which must be continuous, seems at the moment to put the implementation of computer-assisted instruction beyond the bounds of possibility. This is more fully discussed later. Nevertheless this does not mean that the whole prospect is therefore sterile or that developments must forthwith cease. Costs in various fields are decreasing; interest is spreading; and it is not totally unlikely that the point may be reached when the cost-benefit analysis shows that computer-assisted instruction is not such an uneconomic proposition after all.

§6,2: Types of Programs

Patrick Suppes, of Stanford University, has divided into three types the ways of interacting with a computer:-

1. A computer can provide an individual drill and practice system, suitable for work where a lot of practice is needed, e.g. elementary mathematics, reading, the start of foreign languages, elementary science.
2. A tutorial system can be used where the lesson can proceed at a pace that is suitable, where bright children need not be bored, and slow children need not be forced into making errors all the time.
3. A dialogue system could be developed depending on free conversation between the student and the computer.

These three general divisions can probably be expanded to include methods for the following operations:-

1. Problem solving.
2. Simulation, i.e. simulation of situations in economics or experiments in chemistry, etc.
3. Marking answers, analysis of errors, keeping records of progress, remedial work, i.e. all the mechanical work which at present a teacher is expected to do, and which a machine can handle very efficiently, leaving the teacher free to work with the pupils in situations beyond the scope of a mechanical device.
4. Guidance and counselling and decision-making.
5. Information retrieval.
6. A variety or combination of these.

§6.3: Work Being Done with Computer-assisted Instruction

§6.3.1: In the United Kingdom

In Britain, work has been developed along some of these lines by different groups and organisations. At first, work on computer-assisted instruction got off to a slow start, but interest is growing even though money seems to be in short supply. There are various spheres of activity; some of these will be mentioned below.

(a) Organisations interested in the development of computer-assisted instruction. In London in April 1969 there was the Conference of the Organisation for Programmed Learning and Educational Technology. At this there were some papers on computer-assisted instruction, and these with others will probably be published later.

The Open University, which will make use of the B.B.C. radio and television programmes, has now said that it is intended to develop computer-assisted instruction for use by students studying on their own.

Three other organisations among others which have shown an interest in this type of instruction are the Glasgow and West of Scotland Programmed Learning Group, the Nuffield Foundation, and the National Council for Educational Technology.

Recently at Kingston-on-Thames there has been set up the Centre for Structural Communication. This is concerning itself partly with educational technology "from the soft end". The research team there is examining the ways in which curriculum development can use computers, rather than considering how computing facilities can be put to work for instruction purposes. In the history course, for example, the students are presented with a list of twenty short responses, suitable for use in answering the type of questions asked. As the problems come up, the students have to select one or more of these as the complete response to the question. If the answers are incorrect or incomplete, the students are routed to further work, and not until the answers are 100 per cent correct does the program continue.

(b) The Elliott Computer-based Learning System. Mrs. M. Harrison has done some work on computer-assisted instruction, using a computer-based system in conjunction with other aids. She used an Elliott 903C Computer and a display unit for film and six buttons marked "Yes", "No", "A", "B", "C", "D". The writer of the program sets out a part of the instructional material in a frame form. This part is then filmed. The learning program was able to have up to 10,000 frames containing sections of the instructional material. Also inside these frames is a special table containing information about the responses. Marion Harrison has given the following example in an article published in Volume 5, No. 1 of "Programmed Learning":-

BUTTON	V.	C.	F.A.	ADDITION
Yes				
No				
A	*		*	F.A.10
B	*	*		+ 6
C	*			+ 1
D	*		*	F.A.11

The information in the table says that only A, B, C or D are valid answers. B is the correct answer. If A or D are given by the student as the answer, the program must take further action by moving to Frame 10 or Frame 11. If C is given, advance one frame. If B is given, advance six frames.

Two routines have been developed for the system. PLOT is used in the development of the program itself, and it can automatically punch the above information on to a control tape. The language used is a simplified form of Algol called PLUM, derived from "Programmed Learning User's Macros". The other routine is used during the actual learning sessions and is called PLACE.

During the learning sessions, the operator sets up the film at frame ZERO. He then inputs PLACE into the computer. Then he enters the starting frame number and the control tape prepared by PLOT. PLACE then finds the starting frame of the film and controls the projection of the lesson material on to the display screen. It makes a note of the button which is pressed by the student each time he makes a response, refers to PLOT, and then takes the necessary action. PLACE also gathers statistics, such as the total time taken, the time taken for each frame, and the number of correct responses.

The whole system can be housed in the Elliott Mobile Van which accommodates ten people. A larger and more comprehensive system is being developed. This is called ECOLE, and Elliott's visualise that future development will include a tape recorder which will be able to talk to the student, a typewriter keyboard to give the student a chance to construct his own answers, and a light pen.

(c) Bosch AVIT. The Royal Navy educationists have pioneered something similar, but simpler. They call their apparatus the Bosch AVIT (Audio-Visual Integrated Trainer). It is used to teach sailors the rudiments of underwater detection. It first used a TV-sized screen, and slides, and was linked to a taped commentary and a programmed instruction book. But work is continuing on this to introduce more complex electronic hardware and software, and a push-button console, which, like Marion Harrison's used in the system described above, will cover multi-choice questions. The chief instructor's comment earlier this year (1969), when he was asked about the success of this new system, was: "We never had people with full marks before; and the experts don't waste their time teaching."

(d) Bernard Dodd. In Sheffield there have been a few interesting projects. One has been carried out by Bernard Dodd, using what he calls "an impoverished array of equipment" in the Department of Psychology in the University. This consists of a small computer, an Elliott 903C with only 8000 store locations, one teletype terminal and one ESL 1024 teaching machine, which controls a random access filmstrip viewer. The material for the lessons has come from the rather dated book by Thouless called "Straight and Crooked Thinking." The work consists of identifying certain types of crooked thinking evident in such sentences as "Women are good organisers" [this assertion is true of some women, but not all]. When an example of this type of crooked thinking is presented, the student is expected to reply by giving the response "AS". The next type of sentence uses words with an emotional overtone, such as "nigger", and gives examples of statements where the clarity of thought is obscured by the emotional reaction. When an example of this type is presented, the student should respond by "EMO". The third type of statement uses a selected example in an attempt to prove a general point, such as : "I have a Ford Anglia. It is always needing repairs. Don't buy a Ford car. They are unreliable." If this type of sentence is presented, the response should be "SEL". Other sentences may be presented to the student which are quite innocuous and which are not examples of illogical thinking.

This program is written in COWSEL, which is a list-processing language. The teacher can write a new piece of program in the middle of the sequence and have it obeyed from then on.

The program adjusts itself to the performance of the student as he works his way through. At first, some frames are presented which contain examples of AS$^{(a)}$, other sentences being innocuous. The next series has some examples of EMO$^{(b)}$, the rest being innocuous. The third series includes some examples of both previous types (ab). The fourth series has examples included of SEL$^{(c)}$; and the last series includes examples of all three types (abc). The pattern of the progression is therefore

a, b, ab, c, abc.

As the student goes through the material, the system analyses his performance. If ever it falls below a certain level, which has been prearranged and read in at the beginning of the lesson, say 75%, he is branched off to remedial material on that section. When his results have improved and his standard has climbed up to the required standard, he returns to the point he left in the main program.

The material used in this program may be criticised, but at least an attempt has been made here to allow a student to work at his own pace and also at his own level.

(e) Max Sime. The whole problem of industrial training has been considered by Max Sime, also working at Sheffield. He sees computer-assisted instruction as the inevitable result which will come about through the following circumstances:

(i) the enormous problems of training and retraining;

(ii) the expertise which is being accumulated through the use of traditional programmed learning;

(iii) the development of computer facilities.

He has worked out a plan for research over twenty-one man-years, which means three years of actual time if seven experts, as he recommends, are employed. He estimates that a plan such as this needs funds of about £123,000 plus computer time.

(f) Author language. Research workers on Honeywell's computer-assisted instruction system are using a programming language which, they claim, "does not require previous programming experience". It is called AUTHOR. The whole set of hardware consists of a medium 1200 C.P.U. with 32,768 characters of main memory, 3 magnetic tape drives, one disc drive, 6 visual display terminals. However, it is claimed that with only 50 per cent more memory the central processor can handle 32 terminals.

(g) Derek Sleeman. Derek Sleeman began work in Leeds in 1967 with an Elliott 903C computer with 8K store. He also used a teletypewriter and a slide- and tape-projector equipped with 50 slides. The work started with poor multi-access facilities. In this work on computer-assisted instruction, Dr. Sleeman says that he considers a multi-disciplinary team to be essential. The first results he has obtained are due to the combined work of educational psychologists, English teachers, teachers of medicine, teachers from the local schools, and experts in computational science. He has now a grant of £68,000 from the Science Research Council to provide an English Electric M21-40 process control computer for three years, but the work was originally undertaken on the Elliott 903C.

This work was on addition bonds (such as 9 + 6, 6 + 5), and 7- and 8-year-old children were the subjects. The addition sums generated by the computer vary according to the errors and the performance of the child. They also vary with respect to the number of columns, i.e. the columns of units, tens, hundreds, thousands, etc.; and with respect to the operation, i.e. plus or minus, or a mixture of both operations; and with respect to the number of carrying figures involved; and so on. If the child makes two mistakes, the computer will stop to explain how to get the right answer. At any time the teacher can have access to an analysis of the work done. The computer will also print out (under the necessary instructions) varied lists of sums for the children to work on in class.

Dr. Sleeman accepts the conclusion which Professor Skinner reached: that immediate knowledge of results - which Skinner in his work with pigeons and rats called "reinforcement" - will improve learning. This immediacy can be provided by the computer, but the claim has not yet been entirely proved or disproved. Another idea which is generally accepted is that children should work on their own, but Dr. Sleeman believes that children may do better in pairs, grouped by ability. Naturally this arrangement would cut the cost of computer-assisted instruction. Now Dr. Sleeman is working with 22 remote consoles. If all of these are working they require, he says, less than 2 per cent of computer time, the rest of the time being used, he says, on routine work.

(h) <u>W.R. Broderick</u>. In June 1969 the "Computer Weekly" reported that the Social Science Research Council had given a grant of £47,570 to the London Borough of Havering. This is to be used at the Royal Liberty School, Romford, during the next two and a half years. Mr. W.R. Broderick, it is reported, is trying "to find out if the type of computer equipment normally installed by local education authorities can be applied to preparing individualised lessons for school children". He does not believe it is necessary to follow the United States pattern of research in computer-assisted instruction. There the emphasis is on large and expensive real-time system with on-line cathode ray tube equipment or teletype terminals. The shortage of money in Britain at the moment makes it impossible to finance this type of research. But Mr. Broderick believes it is not essential to have fast response times. He believes that work could start with off-line computer-assisted learning. This, he says, will be cheap to implement, and he hopes it will be sufficiently general to enable it to be modified with the minimum difficulty to an on-line real-time system when this is possible.

At the Royal Liberty School, there has been an Elliott 903 computer since 1965. A new Elliott 905 is now installed. This has a new backing store, produced by Marconi-Elliott Computer Systems, which has a capacity of 180,000 eighteen-bit words. In addition, a Creed Envoy Data-Printer has been given by I.T.T. Creed.

Mr. Broderick wonders what subjects will be most suitable to use. The subjects chosen should be those widely taught in local schools, ones in which a teacher can be found to write suitable programs. He suggests mathematics, science, geology, economics, technical or engineering drawing. Possibly programs will be used with thirteen- or fourteen-year-olds. Mr. Broderick thinks that the work will be divided into forty-minute "tasks". These will be learning tasks, and promise to be quite different from the work done recently at Crawley's I.C.L. experiment where an Elliott computer has been used to test knowledge acquired during the biology lessons. At Havering, the input will possibly be in the form of answers to a questionnaire which a pupil will fill up when he has worked through the lesson material. The computer will then process the input, and assess the achievement. A new task will then be assigned, or else the computer will make some changes in the task set previously.

The people needed for this project are as follows:-

a full-time programmer;

possibly a full-time teacher;

an operator/programmer;

secretarial staff;

possibly punch operators.

Mr. Broderick himself will spend half his time directing the research.

The experiment is very interesting, because it is an example of a compromise. The budget is fair, but still relatively small because the Social Science Research Council is short of money for this type of work. Nevertheless, people want to see some results fairly quickly. At the same time, there is a shortage of specialist teachers in certain subjects in schools. The real difficulty is likely to be in the writing of suitable material. This is a field in which there are very few people with experience, but it is good to see a start has been made.

§6.3.2: In the U.S.A.

It seems that far more work has been going on in the U.S.A. It started earlier, and is supported by much more generous grants.

(a) Thompson Ramo Wooldridge, Inc. The Army and Air Force maintain a steady interest in this organisation. Here is one example of the way in which they have been doing so. The United States Air Force has supported work in German-English lessons. In this scheme, the student signs on by typing "O". The computer replies like this: "Good afternoon. This will be your German-English lesson number 4. If you are ready to start at once, please type 'S'. If you would like to review the procedure, please type 'p'." So the student possibly types in "S". The beginning of one particular lesson starts with a vocabulary test. The computer allocates marks to the answers, and keeps a total score. This score can go below zero, to at least -240, but at this point it is likely to make some comment like "Dummkopf". However, if the student improves he can earn comments like "okay", "admirable", "hot dog".

(b) Stanford University (i). It is at Stanford University under Patrick Suppes that a great deal of work with schoolchildren has been initiated. A large computer with 200 terminals can handle as many as 6,000 children each day, giving fifteen minutes of drill to each child over an eight-hour shift. It is reckoned that it should soon be possible to increase this, and have at least a thousand terminals and a daily clientele of thirty thousand students.

In 1964-5 Suppes started a program called "The Accelerated Program in Elementary School Mathematics". He undertook this work with a group of thirty-four children in Grade 2, i.e. eight-year-olds. During the school year, the curriculum covered the History of Numerals, Coordinates, Axes of Symmetry, and Planes of Symmetry, Number Bases, Properties of Numbers, and the Concept of Proofs. In the summer session each group came for one hour daily and spent half the time on geometry and half on arithmetic and logic skills.

Work at the terminals went something like this. A problem appeared on the display, e.g.: "— is the L.C.M. of 4 and 9." Twenty seconds was the time allowed to type in the answer. After that "TIME IS UP" appeared. If no answer had been made, the whole thing was repeated. If there was still no answer, it was given on the screen, and was then to be copied. The question was given a third time, and the answer was given again if there was no response. There was a similar procedure for an error. The result was a program something like this (here the pupil's response is marked by an asterisk):-

```
  PLEASE TYPE YOUR NAME.
* ROBERT VALENTINE.
  DRILL NUMBER 604032.
  L.C.M. MEANS LEAST COMMON MULTIPLE.
  — IS THE L.C.M. OF 4 AND 9.
*
  TIME IS UP.
  — IS THE L.C.M. OF 4 AND 9.
* 36.
  — IS THE L.C.M. OF 12 AND 8.
* 23.
  WRONG.
  — IS THE L.C.M. OF 12 AND 8.
* 24.
```

```
  — IS THE L.C.M. OF 15 AND 10.
* 1.
  WRONG.
  — IS THE L.C.M. OF 15 AND 10.
*
  TIME IS UP.  ANSWER IS 30.
  — IS THE L.C.M. OF 15 AND 10.
* 30.
  ........
* S. FOR SUMMARY.
                    NUMBER     PER CENT
  CORRECT             14          70
  WRONG                5          25
  TIMEOUT              1           5

  70% CORRECT IN BLOCK.  70% OVERALL TO DATE.
  GOODBYE, O FEARLESS DRILL TESTER.
  TEAR OFF ON DOTTED LINE.

  - - - - - - - - - - - - - - - - - - - - - - - -
```

In the work on logic, there were different types of question on the main line. If there was an error, the computer went on to a branch line. If there was an error on the branch line, the teacher was called.

Each day the computer kept an account of the problems attempted by each pupil, and the errors he made. The work in Mathematics followed the text-book, "Sets and Numbers", and as each child finished a section of the book he was given a test. The results showed great variety in individual children. Among children working on Books 2 and 3 at the end of the second year, there was a gap of six months. When the whole group was considered, there was a gap of twenty-one months between the top child and the bottom one in the first year's work, and in the second year's work the gap widened to twenty-four months. As time went on, this gap got wider.

Suppes feels that in early arithmetic classes there is a great need for daily drills of five to six minutes each. He has a program for children in Grades 3 to 6, that is for children of nine to twelve years, written on five different levels. All the children start on the middle level. Thirty per cent of the work is always revision. As a child goes through the work, his score is kept, and if his total equals or surpasses 80% he branches up; if he gets 60% or more, but less than 80%, he stays where he is; and if he gets less than 60% he is automatically switched to a lower branch. [Evidently if he is on the top branch and doing well he stays there, and if he is on the lowest level, and doing badly, he stays there since he can go no lower.] At the end of the allotted time the computer notes a number, e.g. 604032 where

6 refers to the grade;

04 refers to the number of the concept, referring to the syllabus;

03 refers to the number of days so far devoted to that concept;

2 refers to the level of difficulty being currently worked.

A full summary of the work of the whole class is always available to the teacher. Suppes considers that education by computer will never take up more than twenty to thirty per cent of a child's time in school.

Suppes sees the great advantage of this type of instruction as being individualised instruction, whereas it has been said that a programmed learning text-book is merely personalised. Every teacher knows that it is impossible really to teach a big class of children all together. Without individual help - and more so in mathematics than in perhaps any other subject - many children are going to fail somewhere, sooner or later, in their learning. It is hard for teachers to be really sympathetic; because after all teachers are in fact teachers because they were the ones who succeeded in learning something, if not most things, at school. The failures were left behind and lost somewhere along the road. Somewhere along the line, they failed, either because their individual difficulties were ignored, or because there were personality difficulties. The last factor has yet to be examined, and it may be that special programs will be needed for the boy who is an extrovert or a bully, and different ones again for the quiet, retiring children. Computer-assisted instruction certainly does not mean the standardisation of learning. In fact, many people claim the exact opposite, and say that for the first time, the teacher will be freed from unnecessary burdens, and will at last be able to concentrate on individual difficulties.

(c) Stanford University (ii). Learning to read under computer control has also been tried at Stanford. The program took three years to prepare and was ready in 1967. Even for a thirty-minute lesson it was estimated that nine thousand commands were executed by the system. There were three types of material in the whole program and these types follow the usual divisions:-

(1) Drill and practice for children in Grades 4, 5 and 6. These children were spread over a wide area in California, Kentucky, Mississippi, but they all

worked through the Stanford computer.

(2) Dialogue programs. These have not been developed very far.

(3) Tutorial programs based on the assumption that no two children follow the same path through the material. Branching can be determined by a single response, or by a history of responses. The computer can even now only deal with relatively simple textual analysis, so the children's responses have to be chosen from a given list, the list of phrases the computer "understands"!

The whole system with all its accessories was developed by Stanford University and I.B.M., and it is relatively complicated. It consists of the following:-

C.P.U.

Disk-storage units.

Proctor stations.

16 student terminals, each of which is made up of the following equipment:

a picture projector (a rear projection device for black and white, or for colour, which can use film strips with over a thousand frames in each strip);

a light pen;

a typewriter keyboard;

an audio system (for prerecorded messages of anything from a few seconds to fifteen minutes in length, recorded on a tape in a cartridge which may contain up to two hours of speaking);

a cathode ray tube television-type screen capable of displaying alphameric characters and simple line graphics. It was possible for an arrow to appear also, as a pointer; this was synchronized with the audio messages.

Here is a simple example of part of a program. On the screen the following display may occur:

DAN SAW THE	TAN FAT MAN RUN	HAT.

Simultaneously comes the audio message:

> "Only one of the words in column two will make sense in that sentence. Touch and say the word that belongs in the sentence."

If the correct answer is given, the next audio message is:

> "Yes, Dan saw the tan hat. Do the next one."

If the wrong answer is given, the audio message is:

> "No. 'Tan' is the word that makes sense. 'Dan saw the tan hat.' Touch and say, 'Tan',"

and as the voice utters the last phrase, the pointer arrow appears to indicate the first word in the second column, "TAN".

This system is one of the most complex so far compiled.

(d) <u>Computerised counselling</u>. Cogswell, Donahoe, Estavan and Rosenquist report from Los Angeles on computerised counselling. To start, there was a meeting of eighty-seven school counsellors from twelve different areas. They said that too much of their time was being spent on information processing; they wanted more time to work with individual students. For the experiment, they chose a High School complex with ten counsellors for three thousand six hundred students, and a Junior High complex having five counsellors for one thousand eight hundred students. The counsellors underwent three two-hour sessions on computer technology so that they should not be unfamiliar with the technical side of the experiment. The team of computer experts then spent thirty-three hours with the counsellors, getting to know their views on computerised interviews.

Finally they evolved the following method:-

(1) A student was given a five-minute lesson on the teletype-writer;

(2) the student's record was then inspected, and the computer typed out the marks for the previous year, and asked the student if there were any problem areas;

(3) if the student said, "Yes," the computer then asked for a description of the problem which it printed out for perusal by the counsellor;

(4) the student was asked if he wanted to stop;

(5) if he did not want to stop, he was then asked if he wanted to go on to college; and if so, which college, and to study what subject; and then the relevant marks were inspected;

(6) if he did not want to go to college, other alternatives were examined.

Here is part of a sample interview. Answers given by the student are marked by an asterisk:-

Please type your ID number and a CR.

* 42.

One moment please.

Is your name Deborah Anderson?

* Yes.

According to my records this is how you did last semester:

Code	Course	Grade
1	P.E.	A
2	English I	A
3	General Science	A
4	European History	C
5	Algebra	B
6	School service	A

Is this correct? If so, type "YES". If not, type "NO".

* Yes.

Are you having any problems with any of these courses? Please type "YES" or "NO".

* Yes.

Type the number of the course that is giving you trouble.

* 4.

What kind of problem do you have in European History? Please type the nature of the problem. A few words will be O.K.

* I don't turn in my work on time.

I see. If you would like to discuss this problem further, make an appointment to see your counsellor. Would you like to continue this interview at this time, or would you like to discuss your problem with your counsellor before you continue? . . . .

The program was tested with forty Grade 9 students. Twenty were interviewed by the computer, and twenty were interviewed by counsellors who went through exactly the same procedure, so that seventy-five per cent of the statements were exactly the same. In most cases there appeared to be no marked preference for the human counsellor or for the computer, though in a few cases strong views were expressed.

(e) "Mapped" statistics course. Another new idea has been used by Ralph Grubb of the I.B.M. Corporation in California. It is true, he claims, that ordinary courses do not adequately cater for individual differences. But, he says, neither do computer-assisted instruction courses give sufficient attention to these differences: some students want to do revision; some want the whole content; some want to browse; and so on.

So for a statistics course he devised a sort of "map" to be displayed on a screen. This consists of interconnecting boxes. The student should point a pen at the section which interests him, and then he is given on the screen a more detailed map of that subsection, and he can then proceed to choose his own work. At any time when he is fed up, or wants to change, he can point his pen at a "target" at the side of the screen. This will cause him to return either to the previous map, or to the main map, or to the glossary. So he can get a greater "magnification", as it were, of a subject, but the structure and perspective is always intact. The whole idea is like a net, rather than a tree.

(f) Program launched by the National Research Council of Canada. Research into Computer-Aided Teaching Systems has been launched by the National Research Council of Canada and undertaken by Information Science Section of the National Research Council's Radio and Electrical Engineering Division. The work is directed by J.W. Brahan and W.C. Brown. The reasons given by Mr. Brown for this development follow the usual lines:-

(i) Education is under pressure because life is becoming automated and more complex.

(ii) One reason for this increasing complexity is that schools are being asked to provide a higher education in a wider range of topics for more and more children.

(iii) More workers are being retrained, or the sphere of their activity is being altered, since more jobs are becoming automated.

(iv) As productivity and leisure time increases, more adults are able to pursue a greater variety of topics, and the field of adult education is rapidly opening up.

(v) Industry has made use of modern technology in many ways. There is no reason why technology should not also be used to tackle problems of "increasing educational productivity".

W.C. Brown feels, like others, that the new schemes will not replace teachers, but they will ensure that the teachers' time is not taken up by routine tasks, nor monopolised by the excessive demands of students who have been absent through illness. Lessons can be tailored to fit the individual.

The N.R.C. Research Program is concerned with the development of input and output equipment, and with information storage and retrieval. The work on curriculum content in education, and the evaluation of the whole scheme is to be left to trained educators. Moreover, the research team do not envisage that more than a small part of a student's time will ever be used in this way. The rest of his time will be filled with tutorials and discussions.

The N.R.C. efforts, therefore, are first to be concerned largely with

(i) the development of terminal equipment;
(ii) the development of random access audio and video storage;
(iii) writing of control programs;
(iv) the development of the use of natural language.

It is felt that a system is needed which can easily be used by a non-technical teacher for (a) writing, (b) monitoring, and (c) updating instructional programs. All this work necessitates cooperation between educational bodies, industry and government, and a framework of committees to look into the problems and possibilities of cooperation was being planned.

It is interesting to see the sort of lesson that is being written, and that these are not confined to mathematical and science subjects. This is part of a geography lesson (answers by the pupil are indicated by an arrow):-

HELLO.
PLEASE TYPE YOUR NAME.
→ JWBRAHAN.
WHICH COURSE WOULD YOU LIKE TO STUDY TODAY?
→ GEO 1.
THIS UNIT CONCERNS FRUIT FARMING. A BOOKLET OR MATERIALS RELATED TO A TYPICAL NIAGARA PENINSULA FRUIT FARM HAS BEEN PROVIDED. AS YOU PROCEED, FOLLOW DIRECTIONS CLOSELY AND ANSWER ONLY AFTER CAREFUL CONSIDERATION. YOUR PURPOSE IS TO ACCURATELY ENVISAGE THE MANY ASPECTS OF FRUIT FARMING. ANSWERS SELDOM REQUIRE MORE THAN TWO WORDS. BEFORE PROCEEDING, SKIM THROUGH ALL THE MATERIALS PROVIDED.
USING AN ATLAS, LOCATE GRIMSBY, ONTARIO.
HAVE YOU LOCATED GRIMSBY?
→ NO.
PERHAPS THE FOLLOWING WILL HELP.
A PLACE MAY BE LOCATED BY FINDING THE PLACE NAME IN THE INDEX OF THE ATLAS AND NOTING THE SYMBOLS WHICH FOLLOW THE PLACE NAME.
FIND RENNES, FRANCE, IN THE INDEX.
WHAT ARE THE SYMBOLS (NUMBER, LETTER AND NUMBER) FOLLOWING THE NAME?
→ 30D3.
GOOD.
THE 30 REFERS TO THE PAGE ON WHICH YOU WILL FIND RENNES, AND THE D3 REFERS TO THE GRID SQUARE. CAN YOU NOW LOCATE RENNES? (YES OR NO).
→ YES.
WELL DONE.
NOW LOCATE GRIMSBY, ONT. STATE THE PAGE AND GRID NUMBER TO SHOW THAT YOU CAN.
→ 16D3.
SUCCESS IS YOURS.
TO WHAT DOES THE 16 REFER? (PAGE OR GRID SQUARE).
→ PAGE.
GOOD.
TO WHAT DOES THE D3 REFER?
→ GRID SQUARE.
WELL DONE.

THE INDEX SYMBOLS, THEN, TELL YOU WHERE TO FIND A PLACE
NAME ON A MAP. ARE YOU NOW ABLE TO LOCATE GRIMSBY?
→ YES.
WELL DONE.

(g) Psychological statistics course. Ralph Grubb organised this course under the I.B.M. Research Computer Teaching Machine Project. Because of the nature of teaching and learning and responding, in many cases only moderate speed is demanded of a computer. The response of even a slow computer, in any case, is probably better than the response of a teacher to thirty individual children! But the storage of vast quantities of material is required; this demands very big and easily accessible memories. However, these requirements can be met by present-day computers. It is the terminal equipment which needs the greatest development today; moreover, different types of courses need different types of equipment. Also the apparatus needs to be strong and reliable, and there needs to be a different emphasis on the importance of various parts of the apparatus. Minor errors, such as missing bits on the display screen, could be accepted; but total machine failure would be unacceptable because whole groups of students would be condemned to inactivity, and it would be difficult to replace a computer-assisted lesson with one of another type, since all the students would be at different points in the material.

For the program on Psychological Statistics, an I.B.M. 650 RAMAC was used. It has a basic ADD time of 0.7 milliseconds. It has a large random-access disk file, storing six million digits of information with a maximum of 0.8 seconds access time. There are various input-output devices, and it is able to handle twenty teaching stations. These consist of computer-controlled typewriters on which the students' responses are typed.

The procedure is as follows:

(i) In this course, the program tells the student to find a certain page in the text-book.

(ii) At the end of the relevant passage, there is a code number referring to a certain problem in the computer memory.

(iii) This number must be typed into the computer, which then types out the problem for the student. Some problems use multiple-choice answers, but most of them are constructed-answer problems.

(iv) The student types in his answer to the problem.

(v) Depending on his answer, he is directed to further paragraphs in his book, or he is given one of a variety of remedial branches to work through.

(vi) After adequate remedial work, he is returned to the text.

The student terminal has undergone considerable development. It consists basically of an I.B.M. 838 station which is a computer-controlled input-output typewriter. To this has been added computer-controlled carriage return, tabulation and colour-control. The engineers have also added a set of five buttons which allow information to be entered, and permit requests for help, for a rest period, or for dictionary assistance.

Teaching stations are connected in two series to the computer through a 652 control unit. Each series works independently of the other, but unfortunately only one typewriter at the terminals in each series can be worked at one time. Although the 652 control unit makes sure that the student terminal next in the queue gets the next priority, this deficiency in the system is obviously not acceptable. The problem is being tackled and improvements are expected.

(h) Test statistics. This course has been used in California with students in teacher training programs. This particular course lasts for up to five hours and is designed to help students in their spare time. The students have a book on measurement and evaluation through testing, "Psychology and Education," by R.L. Thorndike, and the material for the program is taken from this.

If a student wishes to work through this program, he must make an appointment with the computer, between 5 and 9 o'clock in the evenings on any weekday. Students will probably need more than one session to complete the work. Each student must register at the beginning. This is done by the computer which makes a record of the course name, the student's number, his name, and the options he selects during the course.

The console typewriter has upper and lower case characters. It is a 1050 terminal keyboard. At the beginning of the lesson, the computer says, "Sign on," and the student types in his name (which must not vary during the whole of the computer-assisted instruction course) and his number. Advanced students may be told previously by their tutor to omit part of the course, in which case they then type in the words "BRANCH TO", followed by the name of the section where they want to begin. At the end of the session, when the student signs off, the system records the place where he finished and the next time he will be signed on at that point.

Work on this course was started as far back as April 1965. It was completed in June 1966. Debugging went on for about half that time, after which it was tested by students until January 1966. Then forty-six students took the course and commented on it, and their suggestions resulted in further revision.

(j) Chemical concepts. This program was written by an inexperienced post-graduate student in California. It was written in the Coursewriter Language as an experiment to see how far its success might encourage other teachers, with no experience of computer-assisted instruction, to write their own programs. After writing one section, the author was given some professional advice. It was then coded for the computer, and the writer herself then worked through the material as a student would. She thus gained insight into the scope of this method, and of the Coursewriter Language. The program then went through a whole series of correcting, extension, revision, analysis by herself and by other students.

The program was aimed at teaching the terms and concepts of molecular structures. It has been established that if High School students in their first year do not grasp the basic meanings and relationships of these structures, they have great difficulty in the next class in following the material. The lesson material is hard, and students find it difficult to concentrate and learn the facts, so it was thought that computer-assisted instruction, by focussing attention on a small part of the course at a time, might be able to stimulate student interest.

The course has been written to last two or three hours. It can be considered either as an introduction to the subject, or as revision, or as remedial work. Each section is labelled, and a student can ask the system to advance him to certain sections. To do this, he types in the words "GO TO" followed by the label of the section he wants. Another way of skipping certain sections is provided by the program itself. It frequently asks such questions as, "Do you know what a ratio is?" If the student chooses to go through this material on the meaning of "ratio", he will type in the answer, "No". Otherwise he will be advanced to the end of that section. There is also an element of encouragement, or reinforcement. After each student response, the computer makes a quick comment, such as, "Sorry. That's the wrong answer."

(k) <u>Modular arithmetic</u>. This course was written by a graduate student in Mathematics Education at Stanford University. In this case two parallel programs were compiled to make allowances for different ways of learning. One program presented highly abstract material before the material which was actually to be learned. This was called the "advanced organizer" method. The other program presented the actual material to be learned, and then went on to the abstract discussion of it. This was the "post-organizer" method. It is thought that the first of these two methods will usually be more successful for learning. Possibly the other method, since it involves more of the principles of the discovery method of learning, will be more suitable for the transfer of knowledge.

The course was designed for first-year college students to modulus II arithmetic. The material was broken up into small sections, and one concept only was presented in each section of about one hour. If a student worked through the material quickly, he was told to check the time, and if less than fifteen minutes of his hour remained, he should sign off for that day. If more than fifteen minutes remained, he could begin work on the next section. The whole course was planned to take four or five hours to complete and contained material from elementary algebra; the rational number system; first and second degree equations; ratio, proportion and variation; operations with approximate numbers; indirect measurement; functional relationships; logarithms; simple and compound interest; annuities.

(1) Scientific notation. The first year college students at Stanford who take Chemistry have a two weeks' orientation course. This consists of two or three hours' lectures, one hour's "recitation" (both of which take place in a lecture theatre seating one hundred and seventy-five students); and also one hour's laboratory demonstration, and three hours of practical work. For the Orientation Course there is

a students' text-book, "Problem Book for General Chemistry," by Professor James V. Quagliano. In the introduction to the book the author sets out the aims of his course, and describes the sort of help he hopes his book will give to the students. But he knows its deficiencies. He writes, "It is realised that it is difficult to offer just the right amount of help so that the student takes upon himself a reasonable share of the work. The average student can achieve remarkable results if he is but shown rational procedures to be used in solving problems . . ."

So the program written for the computer-assisted instruction course tried to make up for this deficiency. It tries to illustrate how individual instruction can be combined with analytical, testing, drill and reinforcement techniques. The program tries to diagnose the student's failure to understand and stay with him until he has grasped and understood the concept under consideration. Here is part of the program:

```
   SHIFT THE DECIMAL FROM THE ORIGINAL POSITION (AFTER THE
   LAST ZERO) SO THAT IT IS AFTER THE FIRST DIGIT (5) OF
   THE NUMBER 54 200 000.   AND WRITE THE RESULT.
-> 5·42.
   GOOD.   LET'S CONTINUE.
   HOW MANY PLACES HAVE YOU MOVED THE DECIMAL TO THE LEFT?
-> 3.
   NO.   COUNT AGAIN AND TYPE THE ANSWER.
-> 1.
   THE CORRECT ANSWER IS 7.   TYPE IT IN.
-> 7.
   RIGHT.
   NOW WE MUST MULTIPLY 5·42 BY A POWER OF 10.   WHAT IS
   THE POWER?
-> 7.
   THAT'S THE IDEA.
```

NOW WRITE THE NUMBER 54200000 IN THE SCIENTIFIC FORM (YOU MAY OMIT OR INCLUDE THE UNNECESSARY ZEROS)

→ 5·42 x 1(6.

NO, THE ANSWER IS $5 \cdot 42 \times 10^7$ (TYPE IT IN).

→ 5·42 x -

PLEASE REPEAT.

→ 5·42 x 1(7.

WATCH YOUR TYPING AND TRY AGAIN.

→ $5 \cdot 42 \times 10^7$

GOOD. . . . .

(m) Literacy training. The programs cover reading and writing numbers, adding, counting, subtracting, dividing, multiplying, and fractions. Again, they are part of the experimental work undertaken in California. Later on in the course, word problems were to be introduced as part of the reading materials scheme. A computer-assisted instruction register will keep a count of the number of correct answers. If there are five correct answers in a row, the system will switch the user to the next level of difficulty. If he gets five problems wrong in a row he will be switched to the part of the program which goes over the material again, and gives him easier work. He can then work his way up again to a higher level. A slow student may take as much as a week to master one concept, but a quick student may need only one or two lessons.

Reading will be taught differently. The material is for people with an educational standard of about Grade 7, but it is treated in a way suitable for the people concerned. Results gained from using these methods will be compared with the results from control groups, and if they are satisfactory they will be developed further.

The first section in the reading scheme uses what are called "discrimination procedures". A slide projector, controlled by the computer, shows the student a printed word, and this is simultaneously pronounced by a voice coming from a tape recorder, also controlled by the computer. The student has to say this word again and then copy it on the typewriter. If he types it incorrectly, the computer will retype for him the correct letters with spaces where he put the wrong letters. He then must try to fill in the spaces correctly, and this continues until the computer is satisfied. After these word-learning sessions, he goes on the sentences and he is expected to type words into the spaces left in the sentences. Finally, the student has to write his own sentences using words he has learnt.

The second section is on letter patterns and deals with words containing similar sequences of letters, and with rhyming words, plurals, and so on. Again the student is asked to fill in spaces, and the computer uses branching techniques.

In the third section, words are presented in a sentence, where special words are underlined. These have to be matched with definitions given in a list by the system. Clues will be given if necessary, and branching techniques are again used.

In the fourth section, students deal with pronunciation. Words are marked with a "pronunciation key". The student has to pronounce the word and type it on the typewriter. Then he hears the correct pronunciation on the tape recorder.

This is an experimental scheme and an attempt will be made to assess the intelligence and achievement of the students. They are to be asked whether they like the tests and find the methods acceptable. Results are to be compared with the results obtained by students learning through more usual methods. The scheme sounds very complicated, but no doubt a great deal of useful material is being obtained which will help to improve literacy training as well as to increase our knowledge of the capabilities of computer-assisted instruction.

(n) <u>Concepts formulation</u>. This experiment set up in California is not directly concerned with the learning situation but rather with the field of experimental psychology. But it is indirectly of interest to the educationist since it tries to answer questions such as, "To what extent do people with high non-verbal abilities excel when presented with non-verbal material?"

The equipment consists of a display board containing sixty-four cards, on each of which is a non-verbal configuration. Examples of these are: (i) an oval shape, coloured black and enclosed by a black rectangle; (ii) two black circles, enclosed by a rectangle made of dotted lines; (ii) two small black circles enclosed by two rectangles made of dotted lines.

The person in charge of the experiment explains how to use the 1050 student terminal. He then presents one card to the subject, and the subject then has to answer certain questions about the card, defining the group of which it is a member, and using certain abstract concepts. If the student gives incorrect information he is branched off into other parts of the test material.

This experiment is interesting insofar as the investigator is partly involved in the experiment. He can, however, supervise several subjects simultaneously, and thus increase his productivity. The system collects full information about the student's response, including the lapse of time before an answer is recorded, degree of confidence, and so on. Since the experiment is put in program form it has various advantages: it is standardised and yet still personal, for each subject. This factor reduces the possibility of bias or experimental error. Work along these lines may have something to offer those interested in computer-assisted instruction.

(o) Typing. It is not only in the more abstract fields of learning that computer-assisted instruction may be useful. Work has been done in linking a typewriter on which a student is practising for speed with a computer. The computer is able to control the amount of work put out to be copied, and this varies according to the number of errors made by the typist, and even the amount of confidence she evinces, as judged by the pressure on the typewriter keys. If she does well, more material to be copied is put out on the display screen; but as more errors creep in, this amount is reduced. Thus the computer is able to keep the typist practising at a level which demands maximum effort.

(p) Simulation at Yorktown Heights. Another idea is to teach by simulating a set of conditions, and this has been tried out at Yorktown Heights in New York. The children are in Grade 6, which means they are about twelve years old. They have a terminal linked by telephone line to an I.B.M. 1401 Computer. This prints out questions, answers, background information and instructions. A report from the I.B.M. Corporation giving information about this experiment was headed: "Computerised games helping New York youngsters learn how to run a store, a company, or a country." By choosing from various alternatives, and by typing in messages, a child can make decisions which dramatically affect the development of the imaginary country which he is ruling, or which lead to wealth or bankruptcy in his simulated world of business. "Each child," says the report, "can rule over an ancient Sumerian city-state, for three twelve-year periods . . . The worst thing that can happen, after all," it says,"is to have the population disappear because of famine or disasters." It seems that almost every experience can be given to these young children!

These examples give some idea of the range of work that is being undertaken. It is perhaps not the ideas that are lacking at the moment; in fact, some of them seem to be getting almost out of hand. But full implementation of these ideas depends largely on other developments. Lines of future developments, therefore, will now be considered.

§6.4: Possible Future Developments

§6.4.1: Personnel

Far more people need to be far more interested and well-informed. Research teams should contain all sorts of people from psychologists to computer experts. Ralph Grubb maintains that the ratio of author-time to student-time is something like one to three hundred; this means that it takes six or seven man-years to write a course which would last six months at three hours per week.

§6.4.2: Time-sharing

This is an essential ingredient of computer-assisted instruction. Further developments in time-sharing could mean that students do not need to "queue" for the computer's attention, and that the computer's time is used to maximum efficiency.

§6.4.3: Costs

There will be constant efforts to reduce both the capital costs and the running costs of computer-assisted instruction. Yet even now, Suppes has given a figure of 30 American cents per student hour, or something like 3s. This price compares very favourably with the three or four dollars which people seem prepared to pay for individual tuition. It is not clear how Suppes has calculated this sum, and whether he includes in it any share of the cost of capital equipment. However, Ralph Grubb says that his research team would need £100,000 per year to enable them to function for a forty-four-hour week. But in some places where there is great interest in computer-assisted instruction, the education authorities are getting to the point where they believe it is more expensive not to have up-to-date equipment. Soon computers may be included in this class. This problem is dealt with more fully under "Problems of Finance" (§7.5 below).

§6.4.4: Hardware

There are various lines along which development is taking place at the moment in the field of hardware.

1. At the moment output is largely print, whether on the display screen or on paper. Letters are all capitals, and the size does not vary. People who have to read any quantity of this print complain of the "dullness of the printed page". Graphic displays are being introduced, and these could improve the instruction material very much. Colours, and variety in the letters used, would also improve the appearance and attractiveness of the visual displays.
2. Typewriters are often slow and noisy, and operate one letter at a time. People also say that the Cathode Ray Tube produces a sort of glare which is wearing on the eyes. Now there are non-impact printers which spray electrostatically-charged ink on to paper. This is fast and easy to read, but it is expensive. At Pittsburgh, experiments are being carried out with touch- and pressure-sensitive paper.
3. A student response system, such as the one in use at Illinois,

might be developed for use during lecture periods rather than for use with the usual sort of computer-assisted instruction. With this, each student has a six-button switch which he uses to indicate responses put out by a tutor during the course of his lecture. [The responses may be anonymous or can be such that the tutor can identify the students.] The system analyses the responses; notes the delay of each one in responding; and outputs the information to the lecturer who can then adapt the pace of his lecture and the questions which follow. The use of this system would demand quite a lot of flexibility and initiative on the part of the tutor. But it would be salutary for all lecturers to realise, as they run through their material, how little of it, in fact, does get through to their listeners.

4. Optical Readers for reading print mechanically are of three types:

Optical mark readers;

Optical character readers;

Magnetic ink character readers.

The last of these needs characters of a highly stylised nature and of a very high standard of production and this is not normally available from the Printer. The Optical Mark Reader demands that the position of the marks be aligned with the reading cells of the device used, but does not need very precise marks provided they are well positioned.

However, the optical character readers seem the most suitable for development. These scan the characters, and match the patterns they find with a repertoire of stored characters. The quality of the print must be high, because usually the reader will reject doubtful characters rather than risk reading them incorrectly. The computer can order a re-read in cases of doubt, and usually three re-reads are considered to be sufficient. The computer can be programmed to accept characters of varying degrees of doubtfulness, but the paper needs to be of very high quality without any extraneous matter. Letters on the paper are aligned by means of boxes.

It would be a very great step forward in the field of computer-assisted instruction if a student could communicate with a computer by means of writing on paper, rather than by the typewriter. Moreover, at the moment it is unfortunate, and a hindrance to development in this field, that the U.S.A. uses class A standard type face, and on the whole, in Europe, class B is used.

5. Oral communication with the computer would be even better.

The U.S.S.R. Academy of Sciences report that they have a computer which responds to commands prefaced by the spoken word "Slushai" (meaning "Hear"). It understands a vocabulary of fifty-seven words, comprising the ten digits, mathematical terms and link words. After receiving the last word of an oral program, there is an interval of about 0·5 seconds, and then it types out the answer as well as the problem. One report gave, as an example, the problem of finding

$$\sqrt{144\cdot 1445}$$

The working and answer were printed out as follows:-

```
     035000000000000
+++   03144144500
+++   02120060193
```

The first line of figures indicates that the problem is to find a square root. The argument is given in the second line, where the position of the decimal point is indicated by the first two digits. The result is given in the last line, where again the first two digits indicate the position of the decimal point.

Standard Telecommunications Limited (S.T.L.) have also undertaken some research in the problems of oral communication with a computer. The system comes into operation if the computer is given the words, "Speech input please." An attempt has been made to make the computer understand simple commands such as, "Repeat," "Cancel," "Start." It can understand and repeat a series of numbers read out to it, provided the speed and pitch of the sounds is correct. However, in one demonstration of its ability undertaken by someone not familiar with its idiosyncracies, at the first attempt it failed to understand a three-digit number because the voice spoke too fast, and then heard "76" as "28", possibly because the pitch was wrong or the enunciation poor. This is an interesting field of research, and an important one, and a beginning has barely been made.

§ 6.4.5: Software

It is recommended that simpler languages should be devised so that teachers can take a more direct interest in programming for computer-assisted instruction. One likely development is the introduction of machine dependent high-level languages and the correction of errors by the machine itself, or at least the acceptance of programs containing simple errors.

§6.4.6: Error correcting

A system has been developed by Szanzer of correcting spelling mistakes by an "elastic stretching" method. This uses a matrix of twenty-six units in width, since there are twenty-six letters in the alphabet he uses. The letters in the word which is being tested are stretched out so that each row contains letters in alphabetical order. For example the word DIRETCORY, misspelt for DIRECTORY, would appear as follows:

```
        . . . . . . . . . . . . . . . . . . . . . . . . . .
Row 1         D         I                 R
Row 2           E                             T
Row 3       C
Row 4                               O     R             Y
```

If the number of lines in the stretched version remains the same as the number of lines in the correct version held by the computer (see below), the next procedure will be followed:

```
        . . . . . . . . . . . . . . . . . . . . . . . . . .
Row 1         D         I                 R
Row 2           E
Row 3       C                                 T
Row 4                               O     R             Y
```

After comparing the number of lines, the next procedure is to compare the letters and match them line by line. This will isolate the error, provided there is only one.

If the number of lines in the wrong version is different from that in the correct version held by the computer, the letters correctly matched are erased. Then the matching proceeds from the end of the word. One error can then be found. It is up to the programmer then to decide what action should be taken once an error has been detected.

Certainly, if children are to communicate with computers in the future, some allowance will have to be made for spelling mistakes.

§6.4.7: Educational attitudes

Those are possible lines of development in the hardware and software fields. There will also certainly be other developments in the field of education; there will also need to be certain changes in attitudes. Research into ways and means of learning will go forward, and it is quite likely that new techniques will be produced. In fact, with the change in techniques which is already upon us, we need to ask ourselves even now what we are wanting to change in our education.

It is true, for instance, that computer-assisted instruction offers great possibilities of individualising teaching and learning, but is this what we really want? Do we want to emphasise individual differences, or will not computer-assisted instruction rather lessen the importance of individual differences by dealing efficiently with the difficulties caused by them? But in any case, is this individual learning going to lead to self-sufficiency, and even ruthlessness, if it is overdone? How in future are we going to inculcate the principles of cooperation, forbearance, helpfulness? In any case, too, economics are against too much diversity; how much diversity do we really want to encourage, and how much can we afford? Is not conformity a social virtue too?

If programs become freely available, like library books, to those who want to make use of them, will there be a danger of cramming and forcing bright children on as fast as they can go? It is certainly true that children are capable of learning a great deal more than they are usually given credit for. But is this what we really want? Do we want children who streak far ahead intellectually before they are physically or emotionally developed? Today our society is largely ruled by teenagers. Do we want to be governed next by infant prodigies?

At the moment most teaching is fairly public and open to inspection. Teachers are given scope for developing their own initiative and interests, at the same time as they follow the accepted syllabuses. Is there a danger that this autonomy will be reduced, and that personal idiosyncracies, personal interests, will be smothered by the tyrannical rule of the program writers? If widespread facilities become available for personal, private individual learning, how much control will be retained by the general public, by the teachers themselves, or by the Department of Education and Science? How much individualism can society stand before the social virtues are in danger of cracking? Finally, what sort of individualism is to be encouraged, and what sort is to be discouraged?

One criticism levelled against those who are prepared to introduce mechanisation into education is that the status of the teachers is going to be reduced. The teachers, it seems, will no longer be entirely in charge of the teaching. To some extent, they will abdicate from their functions in favour of a programmer. Their job, it is said, will include that of a technician as well as of baby-minder and keeper of records. Just as the learning process seems likely to become more individualised, the teaching process is likely to become less so. What exactly is to be the rôle of the teacher in the future? If programmed learning and computer-assisted instruction were ever to be introduced on a large scale, teachers would have access to a lot more information about their children. There will be a lot more analysis of errors, educational data. But some people are beginning to think that even today we have too much of this, so much so that we cannot assimilate and use what we have at the moment. Is this the state of affairs that we want?

Young children are largely motivated by their desire to please, and in their early years they need the reassuring presence of a large, comfortable mother-figure. The greatest punishment which can be meted out to a little child is to send him away out of sight, or to ignore him. How then are young children going to react to impersonal education? To what extent is person-to-person contact necessary for learning? Is there any motivation in a computer? If a boy is faced with a tree, he climbs it; if a little child sees a puddle of water, he must splash through it. The tree, the water are self-motivating. They have qualities of touch, colour, feel, movement. Is a computer self-motivating?

It is true that, at first, children are fascinated by a machine, and they often get a great deal of pleasure from pressing the buttons and entering their answers. How long does this fascination last? They may get a sense of mastery in their manipulation of the machine, but it may be that this sense of mastery soon turns to boredom when they are dealing with a machine whose response never varies, and which never gives them any surprises. Once boredom has set in, how is the computer going to urge or even force them on? Every job, almost without exception, and certainly learning is no exception, involves periods of tedium. It is not likely that these can be eliminated from education merely by introducing programmed learning or competition with yourself. It is, in fact, frequently found that a tedious, tiresome job only becomes bearable when it is undertaken in cooperation with other people. What is going to replace this social element in education when computer-assisted instruction or programmed learning are introduced on a wide scale? What is going to replace the discipline exerted from time immemorial by the teacher? In a classroom situation a teacher can use a lot of positive motivation. He can issue good marks, or a sweet, or smile with approbation. There is also negative motivation: a frown, a silence, words of exasperation and disapproval, or worse! It is yet to be seen how a computer can be programmed to provide positive or negative motivation, and to issue the equivalent of a sweet or a kick at appropriate moments. It has yet to be discovered exactly how great a part is played by positive and negative motivation in the process of learning.

For all of us, but for young children in particular perhaps, the environment is important. The people with whom the children become familiar are the most important part of that environment, but the friendly aspect of the classroom and its degree of intimacy must also be taken into consideration. The regular routine of the day, and the general organisation, add to the children's sense of security. Already there have been developments in school architecture, and regimented rows of classrooms have become broken up into more attractive units. There is no doubt that usually this is a great improvement. Now educationists have introduced the idea of the "integrated day", which allows children to move at will from one activity or toy to another. The rigidity of the timetable has been broken down, and freedom of choice replaces it to a large extent. There is no doubt that this too is often beneficial. Class organisation is undergoing experimentation with various groupings and "vertical streaming", which means the placing together of children of various ages. This idea takes account of the social environment of the children, and their social standing with others, and their position regarding brothers and sisters, and groups of friends. It has been found that the social atmosphere is of importance in learning. The future seems likely to produce even more breaking down of barriers and systems of organisation. Will classrooms as they are known today no longer exist as such in a few years' time? It may be that they will be replaced by offices and cupboards, filled with teletypes, calculating machines, and learning machines, remote consoles, tape-recorders and players, slide-, strip-, and film-projectors. Perhaps the school day will become so "integrated" that it will cease to exist as an entity. Perhaps children will come during the day to school in shifts, so that the expensive equipment can be used over a longer period, and the education operators, who replace the teaching staff, be employed for longer hours. Relays of adults will be able to make use of the same facilities in the evenings. The education operators will be able to deal with these various groups because their work will be concerned more with machine maintenance and correct manipulation of programs than with the material of the lessons themselves. Perhaps children will not need to come to school at all, in fact. They may be able to stay at home and communicate at any time of day or night, as they wish, with their educators on shift duty by means of remote links to the computer-assisted instruction centre.

These fantasies will soon be becoming possibilities. As they become more possible, the dilemma of the educationist becomes greater. He finds himself facing again the problem that has confronted teachers, rulers and philosophers from before the time of Plato, and ever since. What is the aim of education? And what is this thing called education? Perhaps people today are no nearer a solution than they have ever been, or perhaps it is that the problem and its solution changes from generation to generation. In any case, it is good that new ideas, like computer-assisted instruction, should shake out of their complacency educationists and teachers who are in some respects among the most conservative of people; it is good that the fundamental issues in education are kept before their gaze.

§7: POSSIBLE USES OF COMPUTER-ASSISTED INSTRUCTION IN UNDERDEVELOPED COUNTRIES

§7.1: The Situation in Zambia in 1969

Those who work in any field of education in Britain today must be aware of various aspects of the upheavals going on in schools. If there appears to be at times, in all these changes here, no clear policy of development, how much less so probably can there be any clear outline of development in the underdeveloped countries. There the problems are different, of course, but at least equally great and where resources of manpower and equipment are minimal. The situation in Zambia will be taken as an example of this type of situation.

Out of all the shortages in Zambia, the shortage of skill is overriding. Skilled manpower is short in every sphere of life: business, finance, government administration, industry, engineering, mining, agriculture, communications and transport, building, medicine, education, and more. At the basis is the poor, but improving, standard of education, and the inadequate provision of schools. This is still true of today; the poverty of educational provision in past years has been staggering. On the other hand there is no shortage of boys and girls, of young men and young women, as Tables I, II and III show.

TABLE I: ESTIMATED PAST POPULATION

	1963	1964	1965	1966
African	3,406,900	3,515,900	3,628,400	3,746,700
European	76,000	74,400	70,000	69,000
Asian and Eurafrican	10,900	11,400	11,900	12,300
Total:	3,493,800	3,601,700	3,710,300	3,828,000

TABLE II: ESTIMATED FUTURE POPULATION

	1970	1975	1980	
African	4,284,500	5,034,300	5,915,300	
European	65,000	65,000	65,000	
Asian and Eurafrican	14,000	17,500	21,300	
Total:	4,363,000	5,116,800	6,001,600	

TABLE III: AFRICAN POPULATION BY AGES AT DECEMBER 31, 1966

Year of birth	Age at Dec. 1966	Total		Year of birth	Age at Dec. 1966	Total
1948	18	63,000		1958	8	114,200
1949	17	66,400		1959	7	122,100
1950	16	69,900		1960	6	130,600
1951	15	74,000		1961	5	139,900
1952	14	78,200		1962	4	149,500
1953	13	83,000		1963	3	160,100
1954	12	87,900		1964	2	171,300
1955	11	93,200		1965	1	183,400
1956	10	99,700		1966	00	196,300
1957	9	106,800				
Total African population < 19 years: 2,189,500						

Table III shows that at the end of December 1966, the percentage of the population which was under nineteen years of age was 58%. More than half the population, therefore, was what people in the United Kingdom consider to be of school age or under, or of an age still to be considered for full-time or part-time education or training. Nearly 23% of the total population are under five years of age, and the proportion of young children in the total population shows no signs of abating.

Very few of the rest of the population have any length of education at all, but these have to become the experts and leaders in government, and industry, and all the trades and professions, including that of caring for and teaching the great mass of young people. To build up the education system of the country, the Government has set aside sums of money shown in Table IV:-

TABLE IV: FUNDS FOR EDUCATION

	Recurrent expenditure	Capital expenditure
1965-66	£ 9,791,932	£8,207,217
1966-67	£12,583,129	£9,600,000

These sums may seem small enough to establish and run the whole educational system of a country, but they represent about 25% of the total annual government income. The amounts are likely to increase slightly each year.

There have been fantastic efforts to increase educational provision.

"Self-help" schemes, which include the making of bricks, and the building of schools, resulted in 1966 in an increase of 64,805 in the total enrolment of children in primary schools, over the 1965 figures. Record numbers of enrolments are forecast for the next few years. Nevertheless there are still far from enough places. Only 79% of all seven-year-old children were in school in 1966, and in the Eastern Province this figure was as low as 62%. Some people try to make up for the deficiencies in educational provision by opening unauthorised schools. In Lusaka, the capital, there were at least a dozen of these schools. The education of girls has always lagged behind that of boys. In 1966 in the top class of primary schools (Grade 7), girls only constituted one third of the total enrolment. In Grade 1 the balance is more satisfactory, about 48% of the children being girls. Nevertheless, even the low figures for girls in Grade 7 represent a threefold improvement in the situation over the two previous years.

This may look a fairly encouraging situation. But further problems follow in the wake of the expansion of primary schools. There is a serious bottle-neck between the end of primary education and the beginning of secondary education. In 1966, there were 20,000 children leaving Grade 7 who could not get places in Form I in secondary schools. In 1970 this figure will be 40,000. This is the situation even after an incredible effort in 1966 when the number of places available in secondary schools was practically doubled in one year (see Diagram 1).

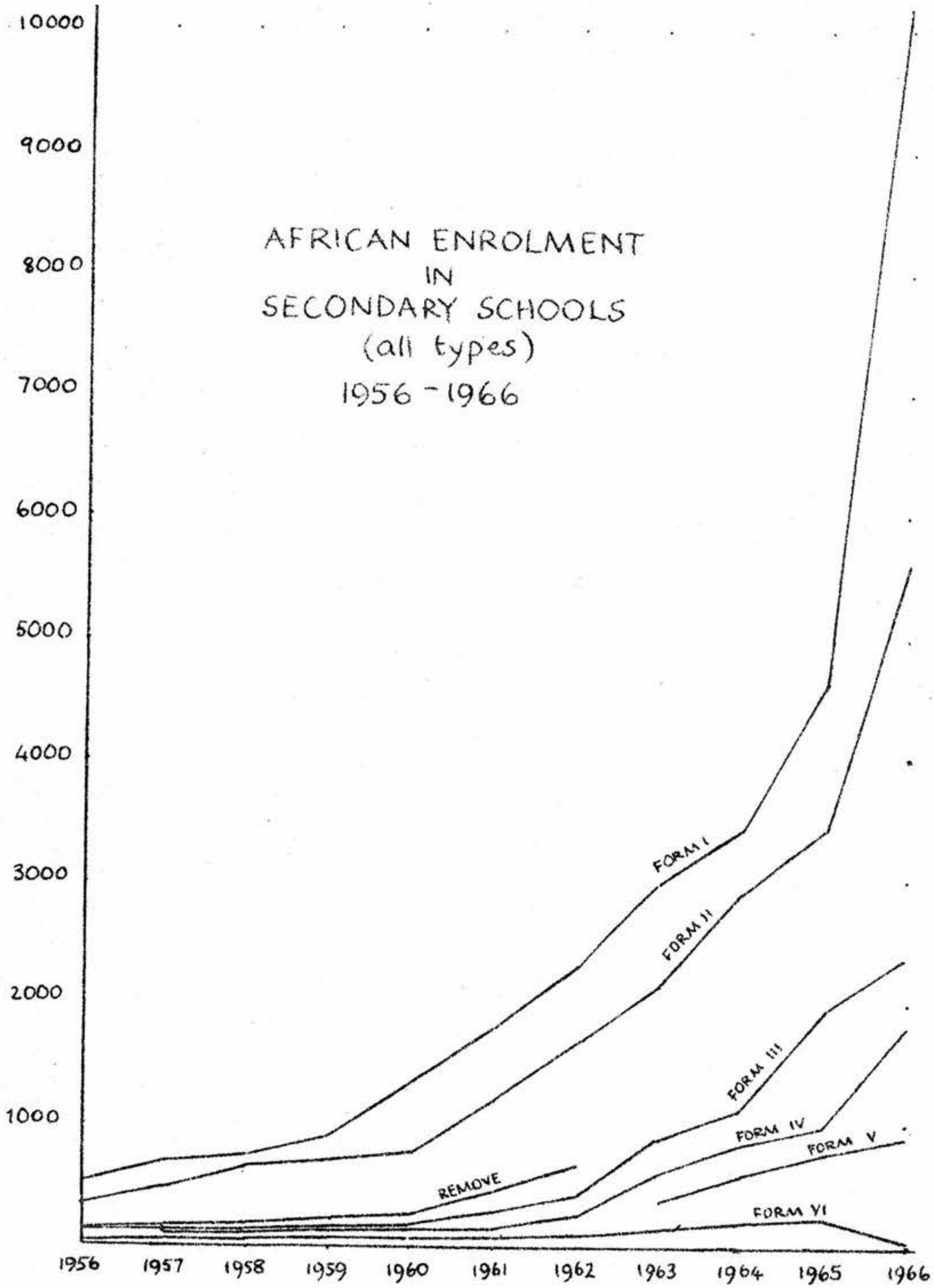

AFRICAN ENROLMENT
IN
SECONDARY SCHOOLS
(all types)
1956 - 1966
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
FORM I
FORM II
FORM III
FORM IV
FORM V
FORM VI
REMOVE
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966

Diagram 1.

The result of this bottleneck is that there are by now almost countless thousands of children and young people with a smattering of education, no real qualifications, no chance of getting any more, virtually unemployable for anything except manual work which they have learned to despise. Moreover, even in unskilled manual work there are few opportunities for paid employment. The number of children shut out from education increases as the standard under consideration gets higher. The 1966 figures show that about four children out of five had a chance of starting school. Of these, one in ten had a chance of getting a place in one of the secondary schools. Of these, again, about one in ten reached the class where pupils sit for the Cambridge Overseas School Certificate Examination. In other words, about one child out of one hundred and twenty-five had a chance of reaching that level. Figures show, moreover, that most of these children come from the urban areas which already contain most of the educational élite of the country. The rural areas, which in many respects represent the areas of greatest need, are becoming by comparison poorer and poorer educationally. The general situation is illustrated by Diagram 2.

For political reasons, it has been expedient to build up the lower part of the educational pyramid. But it is not from here that the gaps in the professions and in the administration and in industry will be filled. The real crisis is perhaps here in the post-primary field, but development here is held up because there are insufficient teachers

THE EDUCATIONAL PYRAMID 1966

(MAINTAINED AND AIDED INSTITUTIONS)

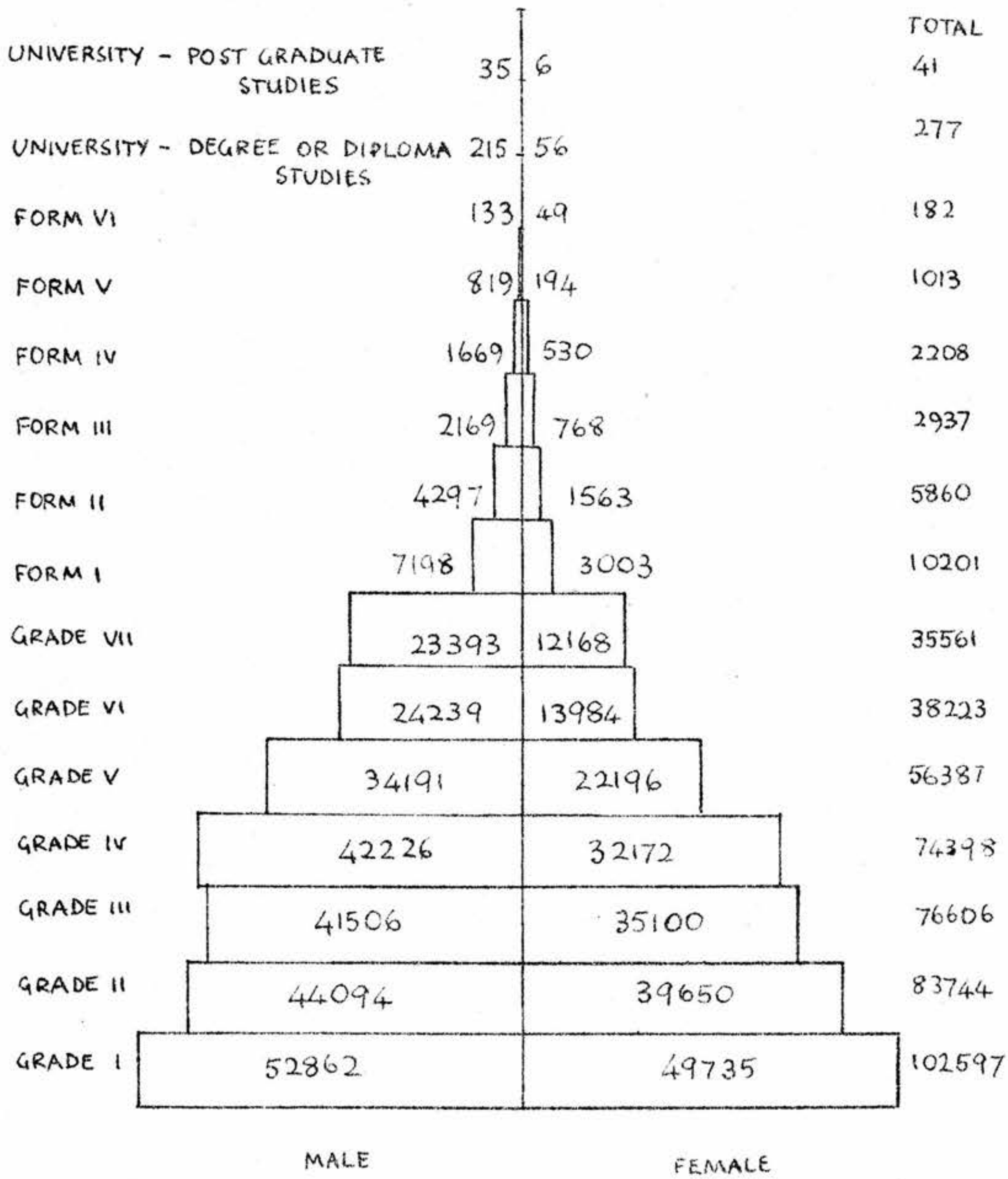


Diagram 2.

and insufficient facilities for further training. In recent years, provision for study in evening classes for those excluded from formal education has increased five-fold. It is the vast rural areas which are often sparsely populated and very difficult to reach, and where the need is often the greatest, that again suffer from inadequate provision of facilities of every sort. In the capital, the Evelyn Howe College of Further Education offers a great variety of courses lasting from a few weeks to a few years; they are offered as day-release courses, evening courses, full-time courses, and they cover practical and academic subjects. Other tertiary education institutions have been opened, nearly every one in an urban area. These include a technical college, an agricultural college, and the University. But for all of these institutions it has not been found easy to recruit local staff, nor indeed students, of a good calibre. Especially short are good students with science and mathematics qualifications.

There is also a grave shortage of good school-teachers. Nearly all graduate teachers are from overseas. Out of 9,325 teachers in primary schools in 1966, 8,600 had themselves never completed five years of secondary schooling. In the secondary schools in 1966, there were 1,290 teachers, and of these 516 were non-graduates. Very few of the 774 graduates were Zambians. In the Teacher Training Colleges there were 147 tutors. Of these, 67 have at the most secondary school education up to the standard of the Cambridge Overseas

School Certificate. Again, most of the others with higher qualifications come from overseas.

It is only if there are sufficient numbers that evening classes can be organised, but even in a big centre like Livingstone with a population of 30,000 there were not enough students enrolling for the External General Certificate of Education Examinations to make the setting up of evening classes possible. The University Extra-Mural Department of Studies is trying out other methods of tuition. To students at this level, they issue duplicated lecture notes, book-lists, and essay questions to be answered, and sent in for marking to the external tutors. They also have two other schemes designed to encourage students. One is the compulsory two-week residential course held each year at the University of Zambia in Lusaka in August. The other scheme is the appointment of tutors for various districts. These tutors are expected to tour round their large districts and make contact with the students and discuss their difficulties.

Pupils and students on the whole are very earnest. Nevertheless, in view of all the facts given above, it is probably not very surprising to find that the pass-rate for examinations is not high. In November 1966, a total of 743 boys and girls gained a full Cambridge Overseas School Certificate. This represents 60.7% of the number who sat for the examination. Other examinations were taken by small numbers of boys and girls. For example, the Associated Examining Board Examinations, and the London General Certificate of Education Examinations, were taken by 88 boys and girls, and the pass-rate was similar. Far more children sit for the Junior Secondary Certificate Examination (taken after two years of secondary education).

If boys and girls, however, cannot get a place in school, they are able to take all of these examinations externally. In 1966, 3,482 young people took the Junior Secondary Certificate Examination as external students. Most of these had probably followed night school classes or correspondence courses. Of these, only 414 passed. At a higher standard, the failure rate is similar. For instance, 352 studied for the A-level examination in various subjects; 59 passed their examination. These results do show that the pass standard is maintained at a fairly high level; and this is a good thing. But they do not give grounds for hope, in spite of the great efforts in the expansion of educational facilities, that the vacancies in the administration and in the teaching profession are going to be rapidly filled by well-qualified, locally-trained men and woemn. The high failure rate also represents a great deal of frustration and wasted effort on the part of the people concerned.

One reason for this frustration and failure at both secondary school and primary school levels is that so much of the material to be studied is of a completely alien character. Too many students in the past who have at last got their certificates have, in fact, qualified in such relatively useless subjects as European History, the British Constitution, Latin or English Literature. They take these subjects because the overseas teachers who have come to fill the gaps in both day classes and evening classes are best qualified in subjects like these. Rural Science, the history of Zambia, engineering, and machine maintenance would be of far more use. But in so many of these more useful fields there is no qualified teacher, or else no source books and no suitable material available. Because developments have come about so very fast, in a lot of their studies Zambian students often find the concepts they are asked to assimilate totally unfamiliar, and totally remote from the environment in which only a few years ago they lived. Often they need a great deal of time and practice to get basic ideas which, owing to circumstances beyond their control, were not acquired in early childhood and are much more difficult to acquire in later life. Zambian students have great qualities of determination, patience and perseverance, and they have high ambitions. But they need constant attention because it is easy for them to go off on the wrong track, since the basic concepts have not been strongly built in in early childhood. They are very conscious of the effects of failure; they are so afraid to fail, so much aware of the difficulties in their way, and so inhibited by much that is strange and foreign in what they are expected to learn that they demand a great deal of slow explanation and patience from their teachers.

These factors were brought out by the reaction of groups of post-Form II students in a training college in Zambia who were given a specially prepared program in booklet form on Elementary Logarithms. The students were mostly in their late teens, and few had more than two years of secondary education behind them. The first response of a high proportion of them was negative in the extreme. It was again largely the result of fear, fear of something new, fear of a new method, and another probable failure to cope with a situation in public and the consequent humiliation they would suffer in the eyes of their fellows. There was also resentment at the fact that the teacher was not going to be at their right hand to provide confidence at every turn. After some stubbornness had been overcome, however, work was started by practically everyone and continued slowly. Most of the students ultimately succeeded in completing the work, and they were asked for their comments. These were what might have been expected. Here are a few:

"We can go at our own speed."

"We can go back if we do not understand."

"All of this I have taught myself, without even the help of the teacher."

"I would very much like to keep this program and take it home with me."

§ 7.2: The Situation in Other Parts of Africa

The situation in other parts of Africa is not altogether different. In the Northern States of Nigeria the population in 1963 was stated to be over 29,000,000. Of these, 15,276 were secondary school pupils, served by 77 schools. Possibly no more than six of the mathematics teachers in all the 281,600 square miles of territory in Northern Nigeria were Nigerian graduates. In the West, the population was under 10,000,000, and there were 636 secondary schools with nearly 90,000 pupils. The situation there was better, but even so only 464 out of the 2,536 secondary grammar school teachers in 1966 were trained graduates.

The children there have a similar chance of going through primary and secondary school to the University as have the children in Zambia. The aim of the Kaduna Ministry of Education in 1967 was that by 1970

(i) one child in four should complete primary education;

(ii) one child in ten from primary schools should proceed to secondary school;

(iii) three out of ten completing the school certificate course should proceed to tertiary education.

This means that the aim is to give one child out of a hundred and thirty-three a chance of tertiary education.

In this situation, J.K. Bunyard, working at the Government Secondary School in Bida, carried out experimental work in programmed learning. He concluded that it had a great deal to offer a country with acute staffing problems in its schools and inadequate educational provision. He found that one of the greatest obstructions to progress was the inability of the students to grasp the significance of the ideas discussed in the programs. English is a second language; the verbal ability of the children in English was often poor. This is due to the fact that they were brought up in a village setting, went to school late, were taught by teachers whose own English was not very competent, taught by methods which did not encourage the use of experience and experiment, but rather passive listening. Bunyard writes: "There is doubt concerning the connection between language and concept formation, but many psychologists and linguists would agree that concepts are very dependent on verbal ability." Any person attempting to use methods which depend on verbal ability in English should therefore be aware of the difficulties facing African children studying in what, to them, is a secondary language.

Nevertheless, there has never really been any doubt either among the Africans or among people from the West that a blending of African culture and Western civilisation - what David Hawkridge calls "acculturation" - is necessary to progress to-day. Technological skill is imperative for progress in the modern world. At present this is largely in the hands of the people from the west; therefore, in order to achieve progress, African people must somehow acquire for themselves the advantages of western education.

Researchers in education have tried to discover the main shortcomings in the education provided for African schoolchildren. In primary education there has been great emphasis placed on literacy and arithmetic skills; yet success has never been very great. One is forced to the conclusion that perhaps the basic difficulties lie deeper. Some skills basic to western culture have been neglected. Cash has described these as basic economic skills, and Hawkridge in his paper on "Programmed Learning and Problems of Acculturation in Africa" describes two of them: pictorial perception and scientific thinking.

Hudson, in papers published in 1960 and 1962, has shown that not only illiterate African subjects have difficulty in "seeing" pictures, but even most African school pupils, including many at high school level, were unable to perceive pictures in three dimensions. European children, on the other hand, by the time they reached the end of their primary schooling, were quite competent at understanding pictorial representation in three dimensions. This difference is due surely to the fact that three-dimensional perception training is entirely absent from African primary education in school, and is entirely ignored in the out-of-school environment in a way which is not true for European children brought up with books, hoardings, advertisements and so on.

Consequently, when Hawkridge tried a programmed text on simple contours with his African schoolchildren he found that there was an almost complete failure to visualise hills or bulges, nor could most draw a reasonably correct cross-section. In a program used by Martin Roebuck, of the University of Ibadan, an adapter and a plug, pictured in one of the frames, were variously identified, he says, "as bag, box, cupboard, 'the thing we use to make our grammer fone to talk', and match, store, bench or chair respectively."

The nature of the basis on which scientific thinking is to be built in African schoolchildren remains largely unknown. Goller points out in her research (on which papers were published in 1965, 1966, 1967) that "the African child is compelled to live in surroundings which lack many experiences provided for children of his age at home in other countries." Using and acquiring any sort of modern equipment contains for the African child an element of mystery and wonder. It seems that the stage of development which Piaget called the intuitive stage lasts longer for African children, and also contains other elements.

It is difficult, then, to use in African schools programs which have been prepared for use in Britain or in the U.S.A. Goller wrote, rewrote, and tested many times programs for use by children in Rhodesia in the fourth, fifth and sixth years of their education. These were used also with people older than those they were written for. She found that the revisions she had to make were largely of three types:

(i) Illustrations had to be changed or entirely eliminated. In certain cases, the use of illustrations seemed to have a positively harmful effect on learning. The use of perspective or shading seemed to confuse many children altogether.

(ii) Verbiage had to be cut down. A cluttered page had an adverse effect on the children's learning. Sentences had to be short. Explanations had to be precise.

(iii) Questions had to be rephrased. The question, "Is A bigger or smaller than B?" would invariably receive the answer, "Yes." These semantic difficulties were sometimes due to poor knowledge of English, but often also to a quite different way of thinking in their own language.

These factors must be taken into consideration when considering the use of computer-assisted instruction in African schools. It would seem that the visual display could be of advantage insofar as it can present clearly a small amount of reading material, capable of being assimilated easily, and without the distraction of the other pages. Photographs shown by a projector may be of more use than the pictorial representation of things under discussion. Possibly the use of audio materials could be further explored; and it would be well to consider how far the sense of touch also could be incorporated into this type of learning. Certainly it is clear that programs cannot be exported wholesale from the U.S.A. for use in the underdeveloped countries of Africa.

§7.3: Towards a Solution

In the Zambian situation computer-assisted instruction has a great deal to offer. In summary, the problems seem to be something like these:-

(a) There is a desperate shortage of well-qualified teachers at every stage of the educational system.

(b) In practically every sphere, there is a great shortage of skilled manpower and qualified personnel.

(c) Pupils and students start their studies with a great variety of preliminary educational attainment and come from a wide variety of backgrounds.

(d) Pupils start with a history of failure; they have a fear of public exposure, and they lack real confidence in their own abilities.

(e) Pupils need, or at least they like and clamorously demand, constant supervision and assurance.

(f) The country is huge and the population is relatively small and thinly spread.

In this sort of situation computer-assisted instruction might help to provide a solution:-

(i) Computer-assisted instruction, once the system had been organised, would help to solve the serious teacher shortage. The present plan of the Zambian government to solve this problem is a temporary measure; they recruit teachers from overseas, and make appointments on short contracts of only two or three years. Once the presence of these teachers is removed, their effectiveness is completely lost. It might be more economical in the long run to employ a small team for that time to write some programs to be used for computer-assisted instruction. When the team's contract expires, and the members of it return home, at least the program would remain behind for future use.

(ii) Zambia has not hesitated to ask for technical assistance in other spheres. For example, advice has been given by the World Bank on the development of Technical Education; and the offer made by the Chinese to survey the north-east of the country in preparation for the building of a rail link to Tanzania was accepted in 1968. Nor have the Zambian authorities been discouraged from undertaking enterprises which were thought necessary merely because outsiders thought the tasks were too difficult. Zambia's rate of educational expansion is breathtaking even by African standards, and exceeds the maximum expansion thought possible by advisers from U.N.E.S.C.O. In Zambia there is enthusiasm and a willingness to experiment, and the country could provide a useful field for experiment in computer-assisted instruction.

(iii) Instruction along these lines, used in conjunction with other modern equipment, such as tape recorders, strips or slides, books and other visual material would help at all levels in the efficient training of more students, more skilled technicians, scientists, engineers, and so on.

(iv) Computer-assisted instruction, with its complex branching capabilities, can be programmed so that the individual differences of pupils or students are catered for. It would also be possible to take into account past standards of attainment and experience. It is not easy to adapt printed text-books to individual students.

(v) Since learning by computer involves individualised instruction, it seems that this would be a most suitable method for the many children and young people who are afraid of making mistakes in public.

(vi) With present facilities offered by telelinks and remote consoles, distance need be no drawback. It is true that in many of the rural areas there is at the moment no mains electricity supply. This state of affairs is not true of all the country, however, and many rural centres do at the moment have electricity and still lack every opportunity for education at anything beyond the lowest grades. Such places would be suitable for linking up.

(vii) Zambia is a country in which industry and commerce play a big part in the economy. Already the number of computers installed is counted in dozens. Even in 1968 the University was offering computer courses.

If the introduction of computer-assisted instruction were undertaken, present attitudes to schooling would need to be changed. But, in fact, they are changing already. Nevertheless still many young people there feel that the burden of both learning and teaching must rest on the teacher, not the pupil. If a child fails his examination, the fault is laid at the door of the teacher. In the past there may have been some reason for this way of thinking, but it is unacceptable today. As more opportunities become available, it may be found that a teacher is not really necessary, after all. Nevertheless, a computer can offer many of the qualities which a teacher possesses. Computer-assisted instruction can give children the feeling that the computer is almost a friend. A child's answers are marked immediately; he can be given encouragement or a reprimand without offence or personal vindictiveness; records of progress and details of failure can be minutely recorded. In fact, this is far more than teachers are able at the moment to do for each child.

A few years ago children in the Australian outback were deprived of educational opportunities. There was a time when the suggestion that these children in remote areas should be taught by radio links would have been considered outrageous. Lack of equipment and personnel would have been given as excuses; people would have said the enormous expenses could not be undertaken in view of the small returns likely to be gained. But today this method of teaching has been accepted as a commonplace.

Nevertheless, today even in developed countries like Britain and the U.S.A. the introduction of computer-assisted instruction has many critics. Mr. Christopher Gane says, "To advocate computer-assisted instruction is rather like asking a man bicycling in the rain to buy a Rolls rather than a mini when he can't even afford a mini." He considers that the advantages which computer-assisted instruction might bring would also be brought much more cheaply by the introduction of programmed self-instruction text-books. Some of the arguments he produces in favour of books must be accepted, but in one respect books like these cannot hope to make the impact on an underdeveloped country which they would make in Britain. In Britain, books are a normal feature of the everyday environment, yet even here many people have difficulty in going through a serious book. In an underdeveloped country, books are rare objects, especially in rural areas. Even a trained teacher in a rural area has only two or three books. People have a respect for them, but they are far from being part of the normal culture. Students do not find them easy to read; in many cases, it would seem, they are at the moment almost a hindrance to learning if other means are available. It is the mass of print and the regiments of words lined up, row on row, on each page which produce a paralysing effect on people who have not grown up with a daily newspaper and a house which, if not full of books, does at least contain some familiar tomes. If people like this are going to be asked to rely on programmed texts for their instruction, many will give up before they embark on the enterprise. If the whole text of the program could be hidden from view, and revealed only a little at a time, the instruction material would not seem so terrifying. Computer-assisted instruction could help to overcome this barrier.

§7.4: Type of System Required

Much of the research in the field of computer-assisted instruction has been undertaken by I.B.M. This began about 1961 when experiments were performed with a modified 650 data processing system and specially designed electrical equipment which connected student terminals to the computer.

Since those early days, the equipment has been enlarged, and the following now seems basic equipment:

(a) Magnetic disk files to store instruction material and students' records.

(b) A central processing unit acting as the interface between student terminals and the instruction material stored in the disks.

(c) A multiplexing unit which directs messages between the terminals and the computer.

(d) I.B.M. 1050 data communication terminals.

The latest system to be developed is called the I.B.M. 1500 instructional system, and it has as many as thirty-two student terminals. The terminals include display screens, typewriters, electronic light pens, tape recorders and slide- and strip-projectors. The number of terminals could possibly be increased to one hundred and fifty, and the price of the whole system might be in the region of £1½ million, but it is not yet produced for general distribution and is still in the development stage so it is not easy to get any but very rough estimates.

§7.5: Problems of Finance

There are still, of course, two major obstacles to the widespread and immediate introduction of computer-assisted instruction in underdeveloped countries. Firstly, there is the problem of finance. Secondly, it is not simple or quick to write suitable programs.

With regard to the shortage of programs, it can only be said that the field is expanding and that programs are indeed being written. One cannot say how long this shortage would last if computer-assisted instruction were developed seriously.

Then with regard to the question of finance it does not seem that the fact that enormous sums of money would be needed is in itself a sufficient reason for not considering the possibility of implementing computer-assisted instruction, and for considering its implications. It is largely a matter of what is considered to be of paramount importance at a particular time. For instance, in 1960 the colonial government had not one secondary school for Zambian girls. (It is true that there were in the whole country, three times the area of Britain, two grant-aided secondary schools for girls which were run by the churches; and there was one government secondary school for boys which once graciously accepted a girl into the science sixth form.) Now, a few years later, there are over a hundred secondary schools open to boys and girls of any race. Until the Unilateral Declaration of Independence made imperative the opening of a road to the north, the Zambian government and its predecessors had always imagined it was too expensive to tar the five hundred miles of road to the borders of Tanzania from the capital. Since the Unilateral Declaration of Independence, however, it has been considered imperative and it has been done. More than that: the scheme to build a railway across the same stretch of country has been nothing but a dream since the days of Cecil Rhodes. Today in circumstances of great stringency and economic crisis there is a team of surveyors, Chinese, it is true, preparing the ground for this enterprise. Under circumstances like these, it does not seem entirely sterile to consider the usefulness of introducing computer-assisted instruction.

So with regard to the expense, perhaps it would be useful to consider here in more detail what some experts in the field have estimated to be the likely cost of computer-assisted instruction.

Patrick Suppes has discussed the cost of introducing such facilities into primary schools in the U.S.A. "Today," he says, "to equip every elementary-school classroom with a console connected by telephone lines to a computer located at the school district office or some nearby central point would cost approximately $2,000 per terminal, including the cost of curriculum development and preparation." But he considers that this cost is likely to be reduced to half that figure by further development and mass production. He considers there may be a million elementary-school classrooms in the U.S.A., so the total cost might be a thousand million dollars. This might be spread over a ten-year period. In that period, the U.S.A. is likely to spend five hundred thousand million dollars on education, a figure which after all represents only 5% of the gross national product. The cost then of equipping every elementary-school classroom with a terminal would be over a ten-year period only 0.2% of the total spent on the education program. There are other expenses to be considered, but, looked at in this light, the enterprise seems to be more of a possibility than was assumed before.

J.C.R. Licklider has some further remarks on the economic aspects of computer-assisted instruction. He calculates that a research development project is prepared to spend as much as thirty-five dollars per student-hour in computer-assisted instruction, but this figure is not realistic for day-to-day use of computer methods in the classroom. He takes the view that the key to the solution lies in the more efficient development of time-sharing. Necessary for this is a large, fast machine, because this is capable of dealing with a very great number of students (at the moment, possibly most large computers can only cope with a maximum of between one and two hundred students, and experiments of this size even are still in the developmental stage); and also a large, fast machine costs less per single, elementary operation than a slow one. The Digital Equipment Corporation has developed a system resulting from the thinking of E. Fredkin and B. Gurly which allows for efficient time-sharing. It is called the "sequence-break" system and has been used on one of their PDP-1 computers. It uses a small amount of hardware and some programming to make use of a function employed until recently only on the most expensive computers,but which, Licklider thinks, will be widely available on many computers in a few years' time. The system allows sixteen users (or multiples of sixteen given more hardware) to operate apparently simultaneously.

The amount of time a computer takes to deal with responses from a student depends mainly on two factors: (1) time needed by the computer to accept the successive characters which comprise the student's response, and (2) time needed by the computer to process the whole response, select suitable material for the next step, and dispaly it. According to Licklider, the PDP-1 computer needs about fifty micro-seconds per character to accomplish the first process described above. If the computer had nothing to do but accept responses from students who typed continuously at the rate of ten characters per second, it could therefore handle between five hundred and a thousand students.

The second process needs more time and this depends on the degree of complexity of the program. As programming becomes more sophisticated and streamlines, the speed can be increased considerably.

Licklider has made calculations based on these facts, and concludes that, at a fairly conservative estimate, a computer of the sort he has mentioned can efficiently operate thirty-five typewriters. This would necessitate additional memory to hold more material, but the total cost would remain in the region of one dollar an hour per student for the computer, and half a dollar an hour for the typewriter. The figures, he says, include depreciation costs and commercial overhead.

Some further figures have been obtained on the costs of running an

I.B.M. 360/44. This particular system was running one eight-hour shift, and a rough estimate of the cost per hour was given as follows:-

1. Electricity — 7s.6d. per hour

2. Consumable material — £ 1 4s.0d. per hour

   This figure was considered fairly low and might well be increased. It referred, however only to the hours when the system was actually running.

3. Operating staff — £ 2 10s.0d. per hour

   At the moment five operating staff were employed. Not all of them, however, were on duty all the time.

4. Maintenance costs — 10s.0d. per hour

   Maintenance was done on a contract basis at the rate of 10.0d. per hour to cover a five-day week of eight hours per day, i.e. maintenance costs were £20 per week.

5. Depreciation — £18 10s.0d. per hour

   The total cost price of the system was roughly £250,000, and it was assumed that the system would be "written off" after about seven years. If the computer worked three shifts, i.e. full-time or twenty-four hours a day, the depreciation costs would probably be reduced to less than £7 per hour.

6. Ancillary services — £ 2 0s.0d. per hour

   This item covers services such as window-cleaning, floor-polishing, etc.

7. Ancillary staff — £ 5 10s.0d. per hour

   This item was made up of salaries for programmers, computer manager, etc., but does not include one or two who are paid from other sources.

8. Other items. Perhaps some other items should also be included, such as the cost of punches, rental of premises, rates.

The total cost, therefore, is in the region of £35 per hour. This could be reduced to about £24 per hour if the system ran on three shifts. If there were thirty-two student terminals, the cost of running each of these therefore would be about 15s. per hour for each one. As the system increases in size, costs would increase, but it would also be able to control a greater number of terminals. Other factors are likely to decrease the cost in the next few years. As more mass-production is introduced, costs will go down. Computer systems and programming techniques are likely to become more efficient and to be automated still further. Time-sharing methods will be developed. It is likely that there will be cooperation in the full use of computers between industry and education. Patrick Suppes already contemplates a system which can operate a thousand student terminals, and he feels at the moment that the cost of computer-assisted instruction compares not unfavourably with the cost of private tuition available from human tutors.

These figures depend on the use of existing hardware. Further improvements will surely be made by developments in time-sharing techniques over the next few years. The main economic problems are likely to be in the field of input-output equipment. Displays and controls, to be really useful, must be extremely flexible, but very robust. If many schools over a wide area are to be connected, the wire or cable connections and their maintenance may constitute a considerable part of the financial outlay. Nevertheless, it seems reasonable to think that by the time the educationists are ready to exploit computer-assisted instruction, within the next five or ten years, there will be sophisticated computer facilities available at a cost which is not prohibitive, and may even be comparable with what people are prepared today to spend on private tuition or correspondence lessons and books.

Moreover, in developing countries in particular, education must be looked upon as a major industry. In most industries, there is a considerable capital outlay. The total spent on the salaries of the people who use the capital equipment is, by comparison, fairly small. This situation is reversed in education, where the salaries of the teachers constitute the major part of the expenditure, and only relatively small sums are spent on capital equipment. Perhaps it is not entirely foolish to hope and believe that this tendency may be reversed in the next few years.

In any case, Zambia is a country of ideas and idealism, of great shortages and great struggles. This is the atmosphere which encourages the making and breaking of dreams. And as for the reality, if it is not for today, maybe it is for tomorrow, maybe for very early in the morning.

§ 8: A PROGRAM FOR ADDITION DRILL AND PRACTICE

§ 8.1: The Program

The program given in Appendix I is an attempt to put into practice some of the principles explained above. It is assumed that the program would be kept in the store and called up on to the remote console apparatus at the beginning of a session. Rax used in conjunction with the I.B.M. 2260 remote consoles is not entirely suitable for this type of work with young children. The keyboard is clear, and no "shift" is required when numbers are being entered into the system from the consoles; however, children using these would need to master the "shift" and "enter" keys and know when to use them. To supply an answer at the correct time, the procedure is not very simple. For example, the question

$$\begin{array}{r} 3 \\ +\underline{\ 2\ } \end{array}$$

may be seen on the screen. Then the immediate reaction of a child who knows the correct answer is to type "5". However, the cursor will be situated in the top left-hand corner and "5" will appear up there, quite out of place. Even if the child using the program is adept at getting the cursor in the correct position below the line, this will not satisfy the system. The pupil may want to type this:

$$\begin{array}{r} 3 \\ +\underline{\ 2\ } \\ 5 \end{array}$$

but this is not acceptable. The system will not record any answer at all in this case. First, the child must press the "shift" and "enter" keys. Then the words "ENTER DATA" will appear on the screen. After that the child must press "erase display" and "shift". At this point he should type his answer. Lastly, he must press "shift" and "enter" again, and wait for the next line of output on the screen. The constant pressing of the "shift" and "enter" keys which is required does not make the whole operation very easy.

It is to be hoped that improvements will be made in the design of letters. It would be very much better if the information and instructions displayed on the screen appeared as they do in any normal text. It would also be of advantage, especially to very young children, if the letters and numbers were larger and clearer. Perhaps one day the pupil sitting at the console will be able to ask for a certain size of print suitable for the work he is about to do.

At the beginning of the program the child is first asked for his name. It is possible that he will give both Christian name and surname. But in any case the computer will, in future, address him by his first name. In one program run at Los Angeles by Cogswell, Donahoe, Estavan and Rosenquist, the computer is provided with a list of diminutives which it can use to replace the Christian name given by the pupil. So its final remark to Deborah at the end of the program is, "It's been nice interacting with you. Thank you, Debbie." This use of the child's name makes the computer seem much more human. Similarly, teachers often include the child's name in the remarks made at the end of an exercise which has just been marked. "Well done, Mary" seems so much more personal than simply, "Good."

The instructions which follow in the program may well be either superfluous or too difficult for a small child to follow; and if this is the case, it is likely that the teacher or an older child will set him off on the program. If the person using the program can understand the instructions he will be quite independent of assistance. In any case, it may be useful to have the instructions there for reference.

The child is then asked if he wants to do some adding. It can be assumed that he will already have expressed this wish to the teacher, or he will have been told it is time to do some arithmetic. So he will answer, "Yes," to the computer's question. But the question is not really superfluous. It emphasises the positive motivation and therefore increases it.

The program consists of a hundred questions in the form of addition sums on each of five levels. This arrangement is an attempt to ensure that the instruction is individualised, i.e. it enables the child to work at his own rate and also at his own level. These questions are read in as data; they are not produced at random by the computer according to instructions regarding the number of decimal places, the number of addends, the number of digits, the number of carrying figures, and so on. Using all the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and including all the twin facts like 4 + 4, 6 + 6, and also doublets like 9 + 6, 6 + 9 and 3 + 1, 1 + 3, there are a hundred basic addition facts (Table V). In elementary arithmetic it is essential that all of these facts are practised, learned and tested, just as it is essential - even for a modern schoolchild - for multiplication facts, or "tables" as they are called, to be learned, and any of them produced, without hesitation, on demand. Often a teacher in the classroom will compose sums for children out of his head, or he will ask quick oral questions for practice and testing in class. It is inevitable that certain addition facts will recur repeatedly. Some teachers seem to have a fixation on 4 x 7 but never seem to think of asking 7 x 4, for example. To a child the fact 3 + 2 is a completely different fact from 2 + 3. Other facts will be totally omitted and never occur in questions in class.

A small program was written to collect evidence of this imbalance in oral questions. People were asked to recite, at random, a hundred multiplication facts, these were fed into the computer as data, and a table was then produced to show how many times some facts appeared, and another showing how many facts were omitted altogether. These appear as Tables VI and VII.

From such evidence, it has been found that certain addition and multiplication facts are generally tested far less frequently than others. For

TABLE V: THE HUNDRED BASIC ADDITION FACTS

0 + 0	0 + 1	0 + 2	0 + 3	0 + 4	0 + 5	0 + 6	0 + 7	0 + 8	0 + 9
1 + 0	1 + 1	1 + 2	1 + 3	1 + 4	1 + 5	1 + 6	1 + 7	1 + 8	1 + 9
2 + 0	2 + 1	2 + 2	2 + 3	2 + 4	2 + 5	2 + 6	2 + 7	2 + 8	2 + 9
3 + 0	3 + 1	3 + 2	3 + 3	3 + 4	3 + 5	3 + 6	3 + 7	3 + 8	3 + 9
4 + 0	4 + 1	4 + 2	4 + 3	4 + 4	4 + 5	4 + 6	4 + 7	4 + 8	4 + 9
5 + 0	5 + 1	5 + 2	5 + 3	5 + 4	5 + 5	5 + 6	5 + 7	5 + 8	5 + 9
6 + 0	6 + 1	6 + 2	6 + 3	6 + 4	6 + 5	6 + 6	6 + 7	6 + 8	6 + 9
7 + 0	7 + 1	7 + 2	7 + 3	7 + 4	7 + 5	7 + 6	7 + 7	7 + 8	7 + 9
8 + 0	8 + 1	8 + 2	8 + 3	8 + 4	8 + 5	8 + 6	8 + 7	8 + 8	8 + 9
9 + 0	9 + 1	9 + 2	9 + 3	9 + 4	9 + 5	9 + 6	9 + 7	9 + 8	9 + 9

TABLE VI: THE NUMBER OF TIMES BASIC MULTIPLICATION FACTS WERE USED IN ASKING 169 ORAL QUESTIONS (a x b)

SECOND NUMBER (b)

FIRST NUMBER (a)	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	1	3	2	0	2	0	3	2	0	0	1
1	0	0	0	0	0	2	0	0	0	1	0	1	0
2	0	0	2	1	1	0	0	2	0	1	0	1	0
3	2	0	0	1	3	3	2	1	1	3	0	1	1
4	0	0	1	1	2	2	2	1	1	1	0	1	0
5	0	0	3	0	3	0	2	2	1	2	0	1	0
6	0	0	0	2	4	2	1	1	1	1	0	2	0
7	0	0	3	4	1	1	6	1	0	3	0	0	0
8	0	0	1	1	3	1	2	3	1	2	0	0	1
9	1	0	1	2	4	2	5	2	0	4	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	2	0
11	1	1	2	0	0	0	3	3	0	1	0	1	0
12	1	2	1	2	3	0	1	0	1	0	0	1	3

TABLE VII: THE NUMBER OF TIMES BASIC MULTIPLICATION FACTS WERE USED IN ASKING 169 ORAL QUESTIONS (a x b). THE FIGURES GIVE TOTALS FOR TWO TRIALS.

First Number (a)	Second Number (b) 0	1	2	3	4	5	6	7	8	9	10	11	12
0	2	2	3	5	2	1	4	1	3	4	2	3	2
1	3	1	0	1	1	4	2	0	2	5	2	3	4
2	1	0	3	1	1	2	0	4	1	3	0	3	1
3	1	0	0	2	3	4	3	2	1	4	1	2	2
4	0	0	1	1	2	3	2	2	2	3	0	2	0
5	0	0	3	0	3	1	5	4	2	2	0	4	2
6	0	3	3	2	5	3	3	3	3	2	1	2	0
7	1	0	3	5	2	4	9	1	1	4	1	2	0
8	3	1	2	2	3	1	3	4	2	2	0	0	3
9	1	1	2	2	4	5	5	3	1	6	1	1	0
10	0	1	0	2	0	1	0	0	0	1	0	3	0
11	2	4	3	0	0	3	4	6	0	3	0	2	0
12	3	2	1	3	4	0	1	2	2	2	1	1	6

This table shows that even after 338 questions, 21% of the basic facts are still untested. One fact has been tested nine times.

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instance, questions like 0 x 7 are often omitted. It has also been found from a consideration of children's answers that some facts need more practice than others. One of the most difficult number bonds to master seems to be 6 x 8. Each fact, then, must be included at least once in a practice session, and some facts should be repeated more than once. If a child needs extra practice with certain bonds, this will be evident from his answers, and if necessary the program can be provided with different questions. The program could be developed so that each of the hundred facts is "ticked off" when it is tested and given correctly. Information about which number facts are known could be available on demand by the teacher at any time. Unless meticulous care is taken, a few half-known or wrongly learnt facts can continue to produce errors and consequent difficulties for children for many years. These may result in errors in more advanced work, even though the more advanced methods themselves may have been mastered. A strong house cannot be built on weak foundations!

For these reasons, the questions have been read in as data, and not composed at random by the computer. This latter method would only be acceptable if it were certain that all hundred addition facts were sure to be covered by a hundred questions (as would be the case if the combinations were given in random order). Since there are a hundred questions on each of five levels and since a child working through the program is liable to jump from one level to another, to carry the above reasoning to its logical conclusion it would be necessary to ensure that if question 12 in set 1 contained the bond 4 + 3, question 12 in the other sets should also contain the bond 4 + 3. This has not been done in the program under discussion, but it is one of the improvements which should be carried out.

Once a child has learned the hundred basic addition facts, other difficulties can be introduced. Addition sums can be developed as follows:-

(a) Units only (i) sums to 9, e.g. 4 + 3.
(ii) sums to 18, e.g. 8 + 7.

(b) Tens and units with no carrying

(i) sums to 20, with one addend only above 10, e.g. 12 + 6.
(ii) sums to bigger numbers, where both addends may be above 10, e.g. 22 + 16.

(c) Tens and units with carrying

(i) sums to 30, with one addend only above 10, e.g. 18 + 6.
(ii) sums to bigger numbers, where both addends are above 10, e.g. 28 + 16.
(iii) as above, but where one addend is below 10, e.g. 68 + 7.

(d) Hundreds, tens and units with no carrying.

(e) Hundreds, tens and units with carrying from units to tens.

(f) Hundreds, tens and units with carrying from tens to hundreds.

(g) Hundreds, tens and units with carrying from units to tens, and from tens to hundreds.

N.B.:- (d), (e), (f) and (g) can be varied by using at first three digits in both addends, and later varying the number of digits, e.g.:

$$\begin{array}{r} 184 \\ +\underline{126} \end{array} \qquad \begin{array}{r} 184 \\ +\underline{\ 26} \end{array} \qquad \begin{array}{r} 184 \\ +\underline{\ \ 6} \end{array}$$

(d), (e), (f) and (g) can later be varied by using up to four digits.

(h) More than two addends, but with the same number of digits in each.

(j) More than two addends, with a differing number of digits in each, e.g.:

$$\begin{array}{r} 46 \\ 792 \\ +\underline{\ \ 8} \end{array}$$

Out of these different groups, five sets of sums of varying difficulty were composed as follows:-

SET 1:	The hundred basic addition facts.		
SET 2:	Numbers	1- 36.	Tens and units with no carrying.
		37- 71.	Hundreds, tens and units with no carrying.
		72-100.	Two addends with a different number of digits in each.
SET 3:	Numbers	1- 36.	Tens and units with carrying.
		37- 54.	Hundreds, tens and units with carrying from the units to the tens.
		55- 72.	Hundreds, tens and units with carrying from the tens to the hundreds.
		73-100.	Two addends with a different number of digits in each, and at least one carrying figure.
SET 4:	Numbers	1- 45.	Tens and units with carrying from units to tens, and tens to hundreds.
		46-100.	Hundreds, tens and units, with carrying figures from units to tens, and also from tens to hundreds.
SET 5:	Numbers	1- 20.	Four two-digit numbers.
		21- 30.	Four three-digit numbers.
		31- 50.	Six two-digit numbers.
		51- 75.	Six numbers with a varying number of digits.
		76-100.	Eight numbers with a varying number of digits.

The five hundred sums which were read in as data are given in Appendix II.

At the beginning of the first session, the pupil working through the program starts at number 101. The first digit indicates the level of working or the set; the second and third digits represent the number of the question in that set. For instance, question 1 of set 1 is recorded as 101, and 423 means the question being worked is number 23 of set 4. After the child has been given his starting number, or has entered the number at which he is going to start the present session, he will see a sum appear on the screen. Next he must enter in his answer.

The answer will then be read in. In this program the first ten spaces only will be read. This may be considered insufficient for questions which have numbers of many digits, and, if so, it could easily be altered. The program instructions then deal with the following situations:-

(1) If a pupil makes an error and realises it in time, he may be able to back-space and erase the mistake. He is also allowed to type "X", and follow this with the correct answer. Only the digits after "X" will then be scrutinised by the computer.

(2) If he presses letters or other non-digit keys by mistake, the program will comment on this and tell him to try again. In this program, he is allowed to make only one of these typing errors. If he makes two, he is asked to practise typing before he continues. In that case, the computer will print out the final remarks and then stop. This may seem too severe; but, since boys will be boys, if the pupil is only putting in various comments for fun, comments which the computer is not programmed to deal with,

he is only wasting computer time and may as well be stopped immediately.

(3) If a blank is included in a series of digits, the computer will comment on this, and tell him to try again.

(4) If the pupil types in nothing, or if he puts in some digits or letters terminated by "X", the computer will display on the screen, "No answer. Ask the teacher." It will record an error and continue with the next question.

(5) If the pupil wishes to stop, he must type "STOP" instead of entering an answer. The computer will then print out the final remarks and stop.

Provided some sort of answer, capable of being compared with the correct answer, is put in, the computer will proceed as follows:-

(1) If it is correct, the computer will reprint on the visual display the correct answer and the comment, "Good". It will then proceed to display the next question after the "shift" and "enter" keys have been pressed.

(2) Five running totals are kept by the computer. In the program these are labelled NO, ICORR, KERR, ICO and IWR. The first is the total number of questions in the program which have been attempted. The number done in a particular session can be found by subtracting the starting number for the session. ICORR holds the number of questions correctly answered. KERR counts the number of typing errors. Only one is allowed. ICO keeps the

number of questions answered correctly since work on the current set or level was started. Similarly IWR keeps the number of incorrect answers on that level. If the total of two correct answers is reached and the pupil is working on set 1, he is upgraded to set 2, and so on. If he is already working on the top set, he will stay there. If the maximum of two incorrect answers is reached, he will be downgraded to work on the set below, unless he is already working on the bottom set, set 1, in which case he remains there. When a change to another set is made, the ICO and IWR totals revert to zero. If the teacher wished, a pupil could remain on one level until five or ten or more correct or incorrect answers had been recorded.

(3) If an answer is not correct, an error is not immediately recorded, but the pupil is given another chance. The computer will print out on the visual display unit the question with the incorrect answer, a cross, and the comment, "Wrong. Try again." Then the question is reprinted below, and another answer expected after the "shift" and "enter" keys, etc., have been pressed.

(4) The procedure for the second attempt is then the same as that for the first attempt, with this one addition: at this stage, if the pupil cannot see where his first answer was wrong, he can ask the computer for help. If he types "Help" at this point, he will be told which digit (or digits) of his answer was wrong; if the error may have been in the carrying figure, this is pointed out to him. If he now answers the question correctly, it is

reprinted with the correct answer, and the comment, "Good". If not, it is reprinted with the incorrect answer, and a cross, and the comment, "Wrong".

(5) After a maximum of two attempts the computer proceeds with the next question. The program could be altered to allow for more than two attempts, but with these simple questions, this seems unnecessary. If a child has no idea of the answer, it is not drill and practice which he needs so much as basic teaching or further understanding of the whole process.

The questions in the top set get progressively harder, insofar as the last group contains eight addends, and there are carrying figures from each of the units, tens, and hundreds columns. Here as well the difficulty increases until the last question is reached.

At the end of the program, or when the pupil wants to stop, the following information is put out:-

(i) the percentage correct out of the total done during the present session;

(ii) a suitable comment on the standard reached during this session;

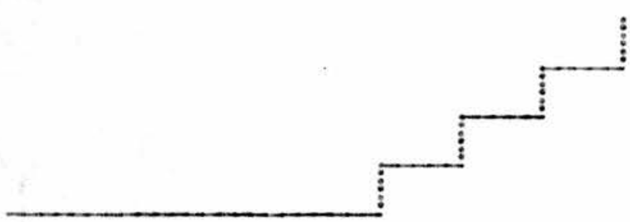
(iii) the finishing number. For example, 512 means that the pupil was working on set 5, and number 12 was the last question which was left incompleted or incorrect. (This will be the starting number for the next session.);

(iv) if all the questions, including question 100, have been finished, the program will automatically stop and a suitable comment will be made.

§8.2: Further Improvements

There are some refinements which could be added to a program like this. It may be useful to record the time taken by a pupil to do his work. Also it may be interesting to have a graphical representation of his progress up and down the five sets. For example, the following two diagrams show up clearly the difference in the work of two children, although they do, in fact, finish at the same point:-

1.



TOP LEVEL

2.

TOP LEVEL

Lastly, it would be interesting to know not only which number facts cause the errors, but also whether these are dependent on the type of question in which they are found. For instance, is a question with many addends and many digits in each addend more likely to cause an error with a basic addition fact like 9 + 6 than a simpler question? For this type of research, a print-out of work done, and further analysis, would be needed.

§9: CONCLUSION

Computer-assisted instruction, then, has made progress in the last few years. In places, especially in the United States, experimental work has been continuing for a considerable time. This has already been shown to produce some results; more are expected; but much more remains to be done. The extent of development in the future depends largely on how much money is made available to improve both hardware and software. The introduction of computer-assisted instruction in the developing countries may seem a pipe-dream today. Yet it could make a big contribution to their progress. Perhaps it is not so much that facilities are lacking as that there is a lack of desire and determination to develop them.

Nevertheless schools today are being forced to accept computers as a subject for study, if not yet as a means of instruction. When there is any big change or innovation in the educational system, all those concerned are forced back to face fundamental questions. This can be a very salutary process. Once more, educators are asking themselves questions which teachers have always asked. What, after all, is society trying to do through education? What part have computers in this process?

Computers certainly have a part to play in the acquisition and storing of more and more knowledge. The volume of knowledge today is increasing at a very great rate, and it seems that only computers can really cope with the mass of information whih is being accumulated. Some people visualise in the future a whole galaxy of interconnected computers which will ultimately contain the sum total of human knowledge. Thus, in theory, everyone will have access to all knowledge. Perhaps this is a frightening prospect, for computers still cannot instruct human beings how to use that knowledge.

Computers may seem to some people possible instruments of tyranny, but it is also possible that they may increase individual freedom. Suppes has pointed out that, just as books freed students from the tyranny of oral recitation and dependence on another human being, so computers can free students from the tyranny of doing things the same way as everyone else, in a way untailored to their personal needs and idiosyncrasies. He maintains that we "can use our modern instruments to reduce the personal tyranny of one individual over another, wherever that tyranny depends on ignorance."

In the meantime, computer studies are certainly providing more information about ways of learning and they are stimulating research into ways of teaching. If men can learn a little more about themselves, that is a good thing in itself.

In the introduction there was no promise that this study would reach any conclusions at all. Perhaps it has only gone round in a circle, and only turned over familiar ground. T.S. Eliot shall have the last word. Some people may think of him as a sceptic; others see him as possessing great faith in man's voyage of self-discovery:

> We shall not cease from exploration
> And the end of all our exploring
> Will be to arrive where we started
> And know the place for the first time.

A P P E N D I C E S

APPENDIX I

BRANCHING PROGRAM FOR SUMS (THTU) WITH NO NUMERICAL RESTRICTIONS, WITH WRONG ANSWERS FOLLOWED BY X

```
C ----------------------------------------------------------------
C BRANCHING PROGRAM (6) FOR SUMS THTU WITH NO NUMERICAL RESTRICTIONS,
C WITH ADDENDS READ IN DURING THE PROGRAM.
C ----------------------------------------------------------------
C
C ----------------------------------------------------------------
C SET UP VARIABLES FOR THE 360/44
C ----------------------------------------------------------------
      INTEGER BLANK/' '/,A/'A'/,B/'B'/,C/'C'/,D/'D'/,E/'E'/,F/'F'/,G/'G'
     2/,H/'H'/,I/'I'/,J/'J'/,K/'K'/,L/'L'/,M/'M'/,N/'N'/,O/'O'/,P/'P'/,Q
     3/'Q'/,R/'R'/,S/'S'/,T/'T'/,U/'U'/,V/'V'/,W/'W'/,X/'X'/,Y/'Y'/,Z/'Z
     4'/
      INTEGER YES/'YES'/,NO/'NO'/
      INTEGER  ONE/'1'/, TWO/'2'/,THREE/'3'/,FOUR/'4'/,FIVE/'5'/,SIX/'6'/
     2,SEVEN/'7'/,EIGHT/'8'/,NINE/'9'/,ZERO/'0'/
      IWR=0
      ICO=0
      LLL=0
    1 DIMENSION IA(100), IB(100), IC(11), IN(20), ID(100), IE(100), IF(1
     200), IG(100), IH(100), II(100), IJ(100), IK(100), IL(100), IM(100)
     3, IP(100), IQ(100), IR(100), IS(100), IT(100), IU(100), NB(2), IA2
     4(100), IA3(100), IA4(100), IB2(100), IB3(100), IB4(100)
C ----------------------------------------------------------------
C GREETING
C READ IN NAME.
C ----------------------------------------------------------------
      WRITE (9,70)
   70 FORMAT (' PLEASE TYPE YOUR NAME.'//' HERE ARE SOME INSTRUCTIONS FO
     2R TALKING TO RAX.  WHEN RAX ASKS YOU A QUESTION AND YOU WANT TO')
      WRITE (9,90)
   90 FORMAT (' REPLY, YOU MUST DO THESE FOUR THINGS.'/'   1.   YOU MUST
     2 PRESS ''SHIFT'' AND ''ENTER''.')
      WRITE (9,110)
  110 FORMAT ('   2.   THEN PRESS ''SHIFT'' AND ''ERASE DISPLAY.''.')
      WRITE (9,130)
  130 FORMAT ('   3.   THEN TYPE IN YOUR REPLY AT THE BEGINNING OF THE L
     2INE.'/'   4.   LASTLY, PRESS ''SHIFT'' AND ''ENTER'' AGAIN.')
      WRITE (9,150)
  150 FORMAT (' PLEASE REMEMBER THE FOUR THINGS YOU MUST DO WHEN YOU ANS
     2WER RAX.')
```

```
      WRITE (9,170)
  170 FORMAT(' IF YOU CANNOT REMEMBER THEM, PLEASE COPY THE INSTRUCTIONS
     2ON SOME PAPER.'///' RAX SAYS, PLEASE TYPE YOUR NAME.')
  179 WRITE (9,180)
  180 FORMAT (' TYPE YOUR NAME LIKE THIS.  PETER WHITE.')
  175 READ (5,190) (IN(I), I=1,20)
  190 FORMAT (20A1)
      DO 240 I=1,20
      IF (IN(I)-BLANK) 240,200,240
  200 IF (I-1) 220,210,220
  210 WRITE (9,215)
  215 FORMAT (' YOU LEFT A SPACE AT THE BEGINNING.  PLEASE WRITE YOUR NA
     2ME AGAIN.')
      GOTO 175
  220 NX=I-1
      GOTO 250
  240 CONTINUE
  250 WRITE (9,260) (IN(I), I=1,NX)
  260 FORMAT (' HELLO ',20A1)
      WRITE (9,261)
  261 FORMAT (' IS YOUR NAME CORRECT ')
      READ (5,301) IYN
  301 FORMAT (A3)
      IF (IYN .EQ. NO) GOTO 179
      IF (IYN .EQ. YES) GOTO 279
  361 WRITE (9,362)
  362 FORMAT (' LET''S START AGAIN.')
      GOTO 179
  279 WRITE (9,280) (IN(I), I=1,NX)
  280 FORMAT (' DO YOU WANT TO DO SOME ADDING TODAY '/' JUST ANSWER YES
     2OR NO, ',20A1)
  290 READ (5,300) IYN
  300 FORMAT (A3)
      IF (IYN .EQ. NO) GOTO 390
      IF (IYN .EQ. YES) GOTO 420
  360 WRITE (9,540)
      WRITE (9,370)
  370 FORMAT (' DO YOU WANT TO DO SOME ADDING TODAY ')
      GOTO 290
  390 WRITE (9,400) (IN(I), I=1,NX)
  400 FORMAT (' I AM SORRY YOU DO NOT WANT TO DO ANY SUMS TODAY.  GOODBY
     2E, '20A1)
      GOTO 5000
  420 WRITE (9,430) (IN(I), I=1,NX)
  430 FORMAT (' I AM GLAD YOU WANT TO DO SOME ADDING, ', 20A1)
      WRITE (9,450)
  450 FORMAT (' IS THIS THE FIRST TIME YOU HAVE MET RAX ')
  460 READ (5,470) IYN
  470 FORMAT (A3)
      IF (IYN .EQ. YES) GOTO 560
      IF (IYN .EQ. NO) GOTO 680
  530 WRITE (9,540)
```

```
 540 FORMAT (' DID YOU FORGET TO ANSWER THE QUESTION '/' PLEASE TYPE YE
    2S OR NO ONLY.')
     GOTO 460
 560 WRITE (9,570)
 570 FORMAT (' YOU WILL SEE A SUM ON THE SCREEN.'/' WHEN YOU WANT TO TY
    2PE IN YOUR ANSWER, YOU MUST DO THESE FOUR THINGS.')
     WRITE (9,590)
 590 FORMAT ('   1.   AFTER READING THE QUESTION, PRESS ''SHIFT'' AND '
    2'ENTER''.'/'   2.   THEN PRESS ''SHIFT'' AND ''ERASE DISPLAY''.')
     WRITE (9,610)
 610 FORMAT ('   3.   THEN TYPE IN YOUR ANSWER AT THE BEGINNING OF THE
    2LINE.'/'   4.   LASTLY, PRESS ''SHIFT'' AND  ''ENTER'' AGAIN.')
     WRITE (9,630)
 630 FORMAT (//4X,'N.B.   IF YOU MAKE AN ERROR, PUT X AND CONTINUE WITH
    2THE CORRECT ANSWER ON THE SAME LINE.')
     WRITE (9,650)
 650 FORMAT (10X, 'IF YOU MAKE A MISTAKE,YOU WILL HAVE A SECOND CHANCE
    2TO GET THE QUESTION CORRECT.')
     WRITE (9,651)
 651 FORMAT(10X,'IF YOU GET AN ANSWER WRONG YOU CAN ASK FOR HELP.  INST
    2EAD OF TRYING A SECOND TIME, JUST TYPE ''HELP''.')
     WRITE (9,652)
 652 FORMAT (10X,'WHEN YOU WANT TO STOP, TYPE ''STOP'' INSTEAD OF THE A
    2NSWER TO THE NEXT QUESTION.'//)
     WRITE (9,670)
 670 FORMAT (' YOUR STARTING NUMBER FOR TODAY IS 101.')
 680 WRITE (9,690)
 690 FORMAT (' WHAT IS YOUR NUMBER ')
C -------------------------------------------------------------------
C READ IN NUMBER.
C -------------------------------------------------------------------
 700 READ (5,710) IROW, (NB(I), I=1,2)
 710 FORMAT (A1, 2A1)
     IF (IROW-ONE)   730,780,730
 730 IF (IROW-TWO)   740,800,740
 740 IF (IROW-THREE) 750,820,750
 750 WRITE (9,760)
 760 FORMAT (' PLEASE WRITE YOUR NUMBER CORRECTLY.  HERE IS AN EXAMPLE.
    2..512.')
     GOTO 700
 780 IROW=1
     GOTO 830
 800 IROW=2
     GOTO 830
 820 IROW=3
 830 DO 1150 I=1,2
     IF (NB(I)-ZERO)  850,940,850
 850 IF (NB(I)-ONE)   860,960,860
```

```
860 IF (NB(I)-TWO)   870,980,870
870 IF (NB(I)-THREE) 880,1000,880
880 IF (NB(I)-FOUR)  890,1020,890
890 IF (NB(I)-FIVE)  900,1040,900
900 IF (NB(I)-SIX)   910,1060,910
910 IF (NB(I)-SEVEN) 920,1080,920
920 IF (NB(I)-EIGHT) 930,1100,930
930 IF (NB(I)-NINE)  750,1101,750
940 NB(I)=0
    GOTO 1110
960 NB(I)=1
    GOTO 1110
980 NB(I)=2
    GOTO 1110
1000 NB(I)=3
    GOTO 1110
1020 NB(I)=4
    GOTO 1110
1040 NB(I)=5
    GOTO 1110
1060 NB(I)=6
    GOTO 1110
1080 NB(I)=7
    GOTO 1110
1100 NB(I)=8
    GOTO 1110
1101 NB(I)=9
1110 IF (I-1) 1140,1120,1140
1120 NBT=NB(I)*10
    GOTO 1150
1140 NO=NBT+NB(I)
1150 CONTINUE
    WRITE (9,1170) IROW, NO
1170 FORMAT (1X,I2,1X,I3)
    NONO=NO
    WRITE (9,1200)
1200 FORMAT (' HERE IS THE FIRST QUESTION FOR TODAY.')
C ------------------------------------------------------------
C READ IN THE QUESTIONS.
C ------------------------------------------------------------
    IBT=0
    KERR=0
    READ (5,1270) (ID(I), IE(I), I=1,100)
    READ (5,1270) (IF(I), IG(I), I=1,100)
    READ (5,1270) (IH(I), II(I), I=1,100)
    READ (5,1270) (IJ(I), IK(I), I=1,100)
1270 FORMAT (10(I4,I4))
    READ (5,1290) (IL(I), IM(I), IP(I), IQ(I), I=1,30)
1290 FORMAT (5(I4,I4,I4,I4))
    READ (5,1310) (IL(I), IM(I), IP(I), IQ(I), IR(I), IS(I), I=31,75)
```

```
1310 FORMAT ( 3(I4,I4,I4,I4,I4,I4))
     READ (5,1330)(IL(I),IM(I),IP(I),IQ(I),IR(I),IS(I),IT(I),IU(I), I=
    276,100)
1330 FORMAT ( 2(I4,I4,I4,I4,I4,I4,I4,I4))
C ----------------------------------------------------------------------
C JUMPING ABOUT THE ROWS.
C ----------------------------------------------------------------------
     NO=NO-1
     ICORR=0
     GOTO (1370,1420,1470,1520,1570), IROW
1370 DO 1390 I=1,100
     IA(I)=ID(I)
139I IB(I)=IE(I)
     IROW=1
     GOTO 1910
1420 DO 1440 I=1,100
     IA(I)=IF(I)
1440 IB(I)=IG(I)
     IROW=2
     GOTO 1910
1470 DO 1490 I=1,100
     IA(I)=IH(I)
1490 IB(I)=II(I)
     IROW=3
     GOTO 1910
1520 DO 1540 I=1,100
     IA(I)=IJ(I)
1540 IB(I)=IK(I)
     IROW=4
     GOTO 1910
1570 DO 1610 I=1,100
     IA(I)=IL(I)
     IB(I)=IM(I)
     IA2(I)=IP(I)
1610 IB2(I)=IQ(I)
     DO 1680 I=31,75
     IA(I)=IL(I)
     IB(I)=IM(I)
     IA2(I)=IP(I)
     IB2(I)=IQ(I)
     IA3(I)=IR(I)
1680 IB3(I)=IS(I)
     DO 1770 I=76,100
     IA(I) =IL(I)
     IB(I) =IM(I)
     IA2(I)=IP(I)
     IB2(I)=IQ(I)
     IA3(I)=IR(I)
     IB3(I)=IS(I)
     IA4(I)=IT(I)
```

```
 1770 IB4(I)=IU(I)
      IROW=5
      NO=NO+1
      GOTO 1820
 1810 KK=1
 1820 IF (NO-100) 1830,1830,5420
 1830 IF (NO-30)  1990,1990,1840
 1840 IF (NO-75 ) 2040,2040,2070
 1850 IF (IWR-2) 1880,1860,1880
 1860 IWR=0
      GOTO (1910,1370,1420,1470,1520), IROW
 1880 IF (ICO-2) 1910,1890,1910
 1890 ICO=0
      GOTO (1420,1470,1520,1570,1910), IROW
C ------------------------------------------------------------------
C TYPE OUT THE QUESTIONS.
C ------------------------------------------------------------------
 1910 NO=NO+1
      KOUNT=0
 1930 IF (IROW-5) 1940,1820,1940
 1940 IF (NO-100) 1950,1950,5420
 1950 WRITE (9,1960) NO,IA(NO), IB(NO)
 1960 FORMAT (///1X,I4,'.',2X,I4/7X,'+',I4/8X,'----')
      IF (IBT-5) 2100,3430,2100
 1990 WRITE (9,2000)NO, IA(NO), IB(NO), IA2(NO), IB2(NO)
 2000 FORMAT (///1X,I4,'.',2X,I4/8X,I4/8X,I4/7X,'+',I4/8X,'----')
      IF (KK-3) 2020,3290,2020
 2020 IF (IBT-5) 2030,3430,2030
 2030 IF (KK) 3520,2100,3520
 2040 WRITE (9,2050)NO, IA(NO), IB(NO), IA2(NO), IB2(NO), IA3(NO), IB3(N
     2O)
 2050 FORMAT (///1X,I4,'.',2X,I4/8X,I4/8X,I4/8X,I4/8X,I4/7X,'+',I4/8X,'-
     2---')
      IF (KK-3) 2020,3290,2020
 2070 WRITE (9,2080)NO,IA(NO), IB(NO), IA2(NO), IB2(NO), IA3(NO), IB3(NO
     2), IA4(NO), IB4(NO)
 2080 FORMAT (///1X,I4,'.',2X,I4/8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/7X,
     2'+',I4/8X,'----')
      IF (KK-3) 2020,3290,2020
 2100 READ (5,2110) (IC(I), I=1,10)
 2110 FORMAT (10A1)
C ------------------------------------------------------------------
C FIND THE POSITION OF THE LAST DIGIT TYPED IN.
C EXAMINE THE LAST DIGIT TO SEE IF IT IS AN X OR AN ACCEPTABLE DIGIT
C OR IF IT IS AN UNACCEPTABLE LETTER OR IF ALL SPACES ARE EMPTY.
C ------------------------------------------------------------------
      DO 2180 I=1,10
      JDIGIT=11
      JDIGIT=JDIGIT-I
```

```
      IF (IC(JDIGIT)-BLANK) 2160,2180,2230
 2160 IF (IC(JDIGIT)-X)     2170,2190,2170
 2170 IF (IC(JDIGIT)-ZERO)  3870,2410,2410
 2180 CONTINUE
 2190 WRITE (9,2200)
 2200 FORMAT (' NO ANSWER.  ASK YOUR TEACHER TO HELP.')
      IWR=IWR+1
      GOTO 1850
 2230 KERR=KERR+1
      IF (KERR-1) 2350,2250,2350
 2250 WRITE (9,2260)
 2260 FORMAT (' TRY TO PRESS THE CORRECT KEYS ON THE TYPEWRITER.')
 2261 WRITE (9,2262)
 2262 FORMAT (' ONLY TYPE THE WORDS ''HELP'' OR ''STOP''.   RAX CANNOT UN
     2DERSTAND OTHER WORDS.')
      IF (KOUNT) 2280,2300,2280
 2280 IWR=IWR+1
      GOTO 1850
 2300 WRITE (9,2310)
 2310 FORMAT (' TRY AGAIN.')
      KOUNT=1
      IBT=5
      GOTO 3420
 2350 IF (KERR-2) 2380,2360,2380
 2360 WRITE (9,2370)
 2370 FORMAT (' THIS IS THE SECOND TIME YOU HAVE PRESSED THE WRONG KEYS.
     2')
 2380 WRITE (9,2390)
 2390 FORMAT (' YOU MUST PRACTISE TYPING BEFORE YOU DO ANY MORE SUMS.')
      GOTO 4900
C ----------------------------------------------------------------------
C TEST THE PREVIOUS DIGIT TO SEE IF IT IS X OR AN ACCEPTABLE DIGIT OR AN
C UNACCEPTABLE LETTER OR AN EMPTY SPACE.
C ----------------------------------------------------------------------
 2410 IF (JDIGIT-1) 2440,2420,2440
 2420 JX=1
      GOTO 2730
 2440 JN=JDIGIT-1
      DO 2500 I=1,JN
      JX=JDIGIT-I
      IF (IC(JX)-BLANK) 2480,2530,2480
 2480 IF (IC(JX)-X)     2490,2720,2490
 2490 IF (IC(JX)-ZERO)  2230,2500,2500
 2500 CONTINUE
      JX=1
      GOTO 2730
C ----------------------------------------------------------------------
C IF AN EMPTY SPACE IS ENCOUNTERED, TEST PREVIOUS ENTRIES TO SEE IF THEY
C WERE CANCELLED BY AN X OR NOT.
C ----------------------------------------------------------------------
```

```
 2530 IF (JX-1) 2540,2720,2540
 2540 JNN=JX-1
      DO 2600 I=1,JNN
      JI=JX-I
      IF (IC(JI)-BLANK) 2580,2600,2580
 2580 IF (IC(JI)-X)     2590,2720,2590
 2590 IF (IC(JI)-ZERO)  2190,2620,2620
 2600 CONTINUE
      GOTO 2720
 2620 WRITE (9,2630)
 2630 FORMAT (' PUT X IF YOU MAKE A MISTAKE.'/' DO NOT LEAVE SPACES.')
      IF (KOUNT) 2650,2670,2650
 2650 IWR=IWR+1
      GOTO 1850
 2670 WRITE (9,2680)
 2680 FORMAT (' TRY AGAIN.')
      KOUNT=1
      IBT=5
      GOTO 3420
C ------------------------------------------------------------------------
C HAVING DEFINED THE LIMITS OF THE NUMBER TYPED IN, CHECK IT AGAINST THE
C CORRECT ANSWER.
C ------------------------------------------------------------------------
 2720 JX=JX+1
 2730 DO 3020 I=JX,JDIGIT
      IF (IC(I)-ZERO)  2750,2830,2750
 2750 IF (IC(I)-ONE)   2760,2850,2760
 2760 IF (IC(I)-TWO)   2770,2870,2770
 2770 IF (IC(I)-THREE) 2780,2890,2780
 2780 IF (IC(I)-FOUR)  2790,2910,2790
 2790 IF (IC(I)-FIVE)  2800,2930,2800
 2800 IF (IC(I)-SIX)   2810,2950,2810
 2810 IF (IC(I)-SEVEN) 2820,2970,2820
 2820 IF (IC(I)-EIGHT) 3010,2990,3010
 2830 IC(I)=0
      GOTO 3020
 2850 IC(I)=1
      GOTO 3020
 2870 IC(I)=2
      GOTO 3020
 2890 IC(I)=3
      GOTO 3020
 2910 IC(I)=4
      GOTO 3020
 2930 IC(I)=5
      GOTO 3020
2950 IC(I)=6
      GOTO 3020
2970 IC(I)=7
      GOTO 3020
```

```
 2990 IC(I)=8
      GOTO 3020
 3010 IC(I)=9
 3020 CONTINUE
      NUMBER=IC(JDIGIT)
      IF (JDIGIT-1) 3050,3100,3050
 3050 IF (JDIGIT-JX) 3060, 3100, 3060
 3060 JTENS=JDIGIT-JX
      DO 3090 I=1,JTENS
      NN=JDIGIT-I
 3090 NUMBER=NUMBER+IC(NN)*10**I
 3100 IF (IROW-5) 3190,3110,3190
 3110 IF (NO-30) 3120,3120,3140
 3120 ISUM=IA(NO)+IB(NO)+IA2(NO)+IB2(NO)
      GOTO 3200
 3140 IF (NO-75) 3150,3150,3170
 3150 ISUM=IA(NO)+IB(NO)+IA2(NO)+IB2(NO)+IA3(NO)+IB3(NO)
      GOTO3200
 3170 ISUM=IA(NO)+IB(NO)+IA2(NO)+IB2(NO)+IA3(NO)+IB3(NO)+IA4(NO)+IB4(NO)
      GOTO 3200
 3190 ISUM=IA(NO)+IB(NO)
C -----------------------------------------------------------------------
C IF THE ANSWER IS CORRECT.
C -----------------------------------------------------------------------
 3200 IF (NUMBER-ISUM) 3350,3210,3350
 3210 IF (IROW-5) 3220,3270,3220
 3220 WRITE (9,3230) NO,IA(NO), IB(NO), NUMBER
 3230 FORMAT (///1X,I4,'.',2X,I4/7X,'+',I4/8X,'----'/6X,I6,1X,'GOOD.'/8.
     2,'----')
      ICORR=ICORR+1
      ICO=ICO+1
      GOTO 1850
 3270 KK=3
      GOTO 1820
 3290 WRITE (9,3300) NUMBER
 3300 FORMAT (6X,I6,1X,'GOOD.'/8X,'----')
      KK=0
      ICORR=ICORR+1
      ICO=ICO+1
      GOTO 1850
C -----------------------------------------------------------------------
C ALLOW A SECOND ATTEMPT IF THE ANSWER WAS WRONG.
C -----------------------------------------------------------------------
 3350 IF (KOUNT) 3380,3360,3380
 3360 KOUNT=1
      IF (IROW-5) 3470,1810,3470
 3380 WRITE (9,3390)
 3390 FORMAT (' ASK THE TEACHER.')
      IWR=IWR+1
```

```
      GOTO 1850
C ------------------------------------------------------------------
C REPRINT THE QUESTION WITH THE WRONG ANSWER IF A SECOND ATTEMPT IS
C BEING MADE.
C ------------------------------------------------------------------
C (A) FOR A BADLY TYPED ANSWER.
C ------------------------------------------------------------------
 3420 IF (IROW-5) 1950,1810,1950
 3430 WRITE (9,3440) (IC(I), I=1,10)
 3440 FORMAT (8X,10A1)
      IBT=0
      IF (IROW-5) 3490,3540,3490
C ------------------------------------------------------------------
C (B) FOR A WRONG ANSWER.
C ------------------------------------------------------------------
 3470 WRITE (9,3480) NO, IA(NO), IB(NO), NUMBER
 3480 FORMAT (///1X,I4,'.',2X,I4/7X,'+',I4/8X,'----'/6X,I6,1X,'X',1X,'WR
     2ONG.  TRY AGAIN.'/8X,'----')
 3490 WRITE (9,3500) IA(NO), IB(NO)
 3500 FORMAT (///8X,I4/7X,'+',I4/8X,'----')
      GOTO 2100
 3520 WRITE (9,3530) NUMBER
 3530 FORMAT (6X,I6,1X,'X',1X,'WRONG.  TRY AGAIN.'/8X,'----')
 3540 KK=0
      IF (NO-100) 3560,3560,5000
 3560 IF (NO-30)  3580,3580,3570
 3570 IF (NO-75)  3610,3610,3640
 3580 WRITE (9,3590)IA(NO), IB(NO), IA2(NO), IB2(NO)
 3590 FORMAT (///8X,I4/8X,I4/8X,I4/7X,'+',I4/8X,'----')
      GOTO 2100
 3610 WRITE (9,3620) IA(NO),IB(NO),IA2(NO),IB2(NO),IA3(NO),IB3(NO)
 3620 FORMAT (///8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/7X,'+',I4/8X,'----')
      GOTO 2100
 3640 WRITE (9,3650)IA(NO),IB(NO),IA2(NO),IB2(NO),IA3(NO),IB3(NO),IA4(NO
     2),IB4(NO)
 3650 FORMAT (///8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/7X,'+',I4/8X,
     2'----')
      GOTO 2100
C ------------------------------------------------------------------
C IF YOU WANT TO STOP.
C ------------------------------------------------------------------
 3670 JS=0
      JDIGIT=JKEEP
 3690 JS=JS+1
      GOTO (3710,3730,3750,3770), JS
 3710 JSTOP=P
      GOTO 3790
 3730 JSTOP=O
      GOTO 3790
```

```
3750  JSTOP=T
      GOTO 3790
 3770 JSTOP=S
      GOTO 3830
 3790 IF (IC(JDIGIT)-JSTOP) 2360,3800,2360
 3800 IF (JDIGIT-1) 2230,2230,3810
 3810 JDIGIT=JDIGIT-1
      GOTO 3690
 3830 IF (IC(JDIGIT)-JSTOP) 2230,3840,2230
 3840 WRITE (9,3850) (IN(I), I=1,NX)
 3850 FORMAT (' I SEE THAT YOU WANT TO STOP NOW, ',20A1)
      GOTO 4900
C ----------------------------------------------------------------------
C IF HELP IS ASKED FOR.
C ----------------------------------------------------------------------
 3870 JH=0
      JKEEP=JDIGIT
 3890 JH=JH+1
      GOTO (3910,3930,3950,3970), JH
 3910 JHELP=P
      GOTO 3990
 3930 JHELP=L
      GOTO 3990
 3950 JHELP=E
      GOTO 3990
 3970 JHELP=H
      GOTO 4030
 3990 IF (IC(JDIGIT)-JHELP) 3670,4000,3670
 4000 IF (JDIGIT)-1)     3670,3670,4010
 4010 JDIGIT=JDIGIT-1
      GOTO 3890
 4030 IF (IC(JDIGIT)-JHELP) 3670,4040,3670
 4040 WRITE (9,4050)
 4050 FORMAT (' JUST GIVE ME A MOMENT AND I WILL SEE IF I CAN HELP YOU.')
 4070 IF (IROW-5) 5110,5130,5110
 4080 IF (IROW-5) 4089,4081,4089
 4081 IF (NO-30) 4082,4082,4084
 4082 ISUM=IA(NO)+IB(NO)+IA2(NO)+IB2(NO)
      GOTO 4180
 4084 IF (NO-75) 4085,4085,4087
 4085 ISUM=IA(NO)+IB(NO)+IA2(NO)+IB2(NO)+IA3(NO)+IB3(NO)
      GOTO 4180
 4087 ISUM=IA(NO)+IB(NO)+IA2(NO)+IB2(NO)+IA3(NO)+IB3(NO)+IA4(NO)+IB4(NO)
      GOTO 4180
 4089 ISUM=IA(NO)+IB(NO)
C ----------------------------------------------------------------------
C SEPARATE DIGITS IN BOTH ADDENDS, CORRECT ANSWER,AND WRONG ANSWER.
C ----------------------------------------------------------------------
 4100 IAU=IA(NO)-IA(NO)/10*10
```

```
      IAT=IA(NO)/10-IA(NO)/100*10
      IAH=IA(NO)/100-IA(NO)/1000*10
      IATH=IA(NO)/1000-IA(NO)/10000*10
      IBU=IB(NO)-IB(NO)/10*10
      IBT=IB(NO)/10-IB(NO)/100*10
      IBH=IB(NO)/100-IB(NO)/1000*10
      IBTH=IB(NO)/1000-IB(NO)/10000*10
 4180 ICU=NUMBER-NUMBER/10*10
      ICT=NUMBER/10-NUMBER/100*10
      ICH=NUMBER/100-NUMBER/1000*10
      ICTH=NUMBER/1000-NUMBER/10000*10
      ISUMU=ISUM-ISUM/10*10
      ISUMT=ISUM/10-ISUM/100*10
      ISUMH=ISUM/100-ISUM/1000*10
      ISUMTH=ISUM/1000-ISUM/10000*10
 4241 IF (IROW-5) 4250,5230,4250
C ------------------------------------------------------------------
C FIND OUT WHERE THERE ARE CARRYING FIGURES.
C ------------------------------------------------------------------
 4250 ICARRU=IAU+IBU-10
      IF (ICARRU) 4290,4270,4270
 4270 JCARRU=1
      GOTO 4300
 4290 JCARRU=0
 4300 ICARRT=IAT+IBT-10+JCARRU
      IF (ICARRT) 4340,4320,4320
 4320 JCARRT=1
      GOTO 4350
 4340 JCARRT=0
 4350 ICARRH=IAH+IBH-10+JCARRT
      IF (ICARRH) 4390,4370,4370
 4370 JCARRH=1
      GOTO 4400
 4390 JCARRH=0
C ------------------------------------------------------------------
C FIND THE DIGIT(S) CONTAINING THE ERROR(S).
C ------------------------------------------------------------------
 4400 IF (ISUMU-ICU) 4440,4410,4440
 4410 IF (ISUMT-ICT) 4510,4420,4510
 4420 IF (ISUMH-ICH) 4660,4430,4660
 4430 IF (ISUMTH-ICTH) 4810,4840,4810
 4440 IF (JCARRU) 4480,4450,4480
C ------------------------------------------------------------------
C TYPE OUT SUITABLE COMMENTS
C ------------------------------------------------------------------
C     (A) FOR ROWS 1,2,3 OR 4.
C ------------------------------------------------------------------
 4450 WRITE (9,4460)
 4460 FORMAT (' LOOK AT THE UNITS.')
```

```
      GOTO 4410
 4480 WRITE (9,4490)
 4490 FORMAT (' LOOK AT THE UNITS.'/' REMEMBER TO CARRY ONE TEN.')
      GOTO 4410
 4510 IF (JCARRU) 4560,4520,4560
 4520 IF (JCARRT) 4600,4530,4600
 4530 WRITE (9,4540)
 4540 FORMAT (' LOOK AT THE TENS.')
      GOTO 4420
 4560 IF (JCARRT) 4630,4570,4630
 4570 WRITE (9,4580)
 4580 FORMAT ('  LOOK AT THE TENS.'/' REMEMBER TO ADD ONE TEN.')
      GOTO 4420
 4600 WRITE (9,4610)
 4610 FORMAT (' LOOK AT THE TENS.'/' REMEMBER TO CARRY ONE HUNDRED.')
      GOTO 4420
 4630 WRITE (9,4640)
 4640 FORMAT (' LOOK AT THE TENS.'/' REMEMBER TO ADD ONE TEN, AND CARRY
     2ONE HUNDRED.')
      GOTO 4420
 4660 IF (JCARRT) 4710,4670,4710
 4670 IF (JCARRH) 4750,4680,4750
 4680 WRITE (9,4690)
 4690 FORMAT (' LOOK AT THE HUNDREDS.')
      GOTO 4430
 4710 IF (JCARRH) 4780,4720,4780
 4720 WRITE (9,4730)
 4730 FORMAT (' LOOK AT THE HUNDREDS.'/' REMEMBER TO CARRY ONE HUNDRED.'
     2)
      GOTO 4430
 4750 WRITE (9,4760)
 4760 FORMAT (' LOOK AT THE HUNDREDS.'/' REMEMBER TO CARRY ONE THOUSAND.
     2')
      GOTO 4430
 4780 WRITE (9,4790)
 4790 FORMAT (' LOOK AT THE HUNDREDS.'/' REMEMBER TO ADD ONE HUNDRED, AN
     2D CARRY ONE THOUSAND.')
      GOTO 4430
 4810 IF (JCARRH) 4860,4820,4860
 4820 WRITE (9,4830)
 4830 FORMAT (' LOOK AT THE THOUSANDS.')
 4840 WRITE (9,4841)
 4841 FORMAT (///' IF YOU CANNOT SEE YOUR MISTAKE, ASK THE TEACHER.')
 4842 WRITE (9,4843)
 4843 FORMAT (' NOW TRY AGAIN.')
      GOTO 3420
 4860 WRITE (9,4870)
 4870 FORMAT (' LOOK AT THE THOUSANDS.'/' REMEMBER TO ADD ONE THOUSAND.'
     2)
```

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 4871 WRITE (9,4872)
 4872 FORMAT (///' IF YOU CANNOT SEE YOUR MISTAKE, ASK THE TEACHER.')
 4873 WRITE (9,4874)
 4874 FORMAT (' NOW TRY AGAIN.')
      GOTO 3420
C ------------------------------------------------------------------
C WORK OUT THE PERCENTAGES.
C ------------------------------------------------------------------
 4900 IPER=ICORR*100/(NO-NONO)
      WRITE (9,4920) IPER
 4920 FORMAT (///' TODAY YOUR MARK WAS ',I3,' PER CENT.')
      IF (IPER-90) 4970,4940,4940
 4940 WRITE (9,4950) (IN(I), I=1,NX)
 4950 FORMAT (' VERY GOOD TODAY, ', 20A1)
      GOTO 5070
 4970 IF (IPER-73) 5010,4980,4980
 4980 WRITE (9,4990) (IN(I), I=1,20)
 4990 FORMAT (' YOU MUST TAKE A LITTLE MORE CARE, ',20A1)
      GOTO 5070
 5010 WRITE (9,5020) (IN(I), I=1,NX)
 5020 FORMAT (' WERE YOU TRYING YOUR BEST TODAY   I HOPE YOU WILL DO BET
     2TER NEXT TIME, ' 20A1)
      IF (NO-10) 5040,5070,5070
 5070 IF (LLL-5) 5071,5053,5071
 5040 WRITE (9,5050) IROW, NO, (IN(I), I=1,NX)
 5050 FORMAT (' REMEMBER YOUR NUMBER IS ',I2,'0',I1,'.  GOODBYE, ', 20A1
     2)
      GOTO 5000
 5071 WRITE (9,5080) IROW,NO, (IN(I), I=1,NX)
 5080 FORMAT (' REMEMBER YOUR NUMBER IS ',I2,I2,'.  GOODBYE, '20A1)
      GOTO 5000
 5053 WRITE (9,5054) (IN(I), I=1,NX)
 5054 FORMAT (' GOODBYE, ', 20A1)
      GOTO 5000
C ------------------------------------------------------------------
C REWRITE THE QUESTION IF HELP IS ASKED FOR.
C ------------------------------------------------------------------
 5110 WRITE (9,5120) NO, IA(NO), IB(NO), NUMBER
 5120 FORMAT (///1X,I4,'.',2X,I4/7X,'+',I4/8X,'----'/6X,I6,1X,'X'/8X,'—
     2—'/)
      GOTO 4080
 5130 IF (NO-100) 5140,5140,5000
 5140 IF (NO- 30) 5160,5160,5150
 5150 IF (NO- 75) 5180,5180,5200
 5160 WRITE (9,5170) NO, IA(NO), IB(NO), IA2(NO), IB2(NO), NUMBER
 5170 FORMAT (///1X,I4,'.',2X,I4/8X,I4/8X,I4/7X,'+',I4/8X,'----'/6X,I6,1
     2X,'X'/8X,'----'/)
      GOTO 4080
 5180 WRITE (9,5190) NO, IA(NO), IB(NO), IA2(NO), IB2(NO), IA3(NO),IB3(
     2NO),NUMBER
```

```
 5190 FORMAT (///1X,I4,'.',2X,I4,/8X,I4/8X,I4/8X,I4/8X,I4/7X,'+',I4/8X,'
     2----'/6X,I6,1X,'X'/8X,'----'/)
      GOTO 4080
 5200 WRITE (9,5210) NO, IA(NO), IB(NO), IA2(NO), IB2(NO), IA3(NO), IB3(
     2NO), IA4(NO), IB4(NO), NUMBER
 5210 FORMAT (///1X,I4,'.',2X,I4/8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/8X,I4/7X,
     2'+',I4/8X,'----'/6X,I6,1X,'X'/8X,'----'/)
      GOTO 4080
C ---------------------------------------------------------------------
C TYPE OUT SUITABLE COMMENTS
C ---------------------------------------------------------------------
C     (B) FOR ROW 5.
C ---------------------------------------------------------------------
 5230 IF (ISUMU-ICU)  5270,5240,5270
 5240 IF (ISUMT-ICT)  5300,5250,5300
 5250 IF (ISUMH-ICH)  5330,5260,5330
 5260 IF (ISUMTH-ICTH)5360,5390,5360
 5270 WRITE (9,5280)
 5280 FORMAT (' THERE IS A MISTAKE IN THE UNITS.')
      GOTO 5240
5300 WRITE (9,5310)
 5310 FORMAT (' THERE IS A MISTAKE IN THE TENS.  EITHER YOUR ADDING OR Y
     2OUR CARRYING FIGURE WAS WRONG.')
      GOTO 5250
 5330 WRITE (9,5340)
 5340 FORMAT (' THERE IS A MISTAKE IN THE HUNDREDS.  EITHER YOUR ADDING
     2OR YOUR CARRYING FIGURE WAS WRONG.')
      GOTO 5260
 5360 WRITE (9,5370)
 5370 FORMAT (' THERE IS A MISTAKE IN THE THOUSANDS.  EITHER YOUR ADDING
     2OR YOUR CARRYING FIGURE WAS WRONG.')
 5390 WRITE (9,5400)
 5400 FORMAT (' TRY AGAIN.')
      GOTO 3420
C ---------------------------------------------------------------------
C THE END.
C ---------------------------------------------------------------------
 5420 WRITE (9,5430)
 5430 FORMAT (' WELL DONE.  YOU HAVE FINISHED THE QUESTIONS.')
      LLL=5
      GOTO 4900
 5000 STOP
      END
```

APPENDIX II

DATA READ IN WITH THE ABOVE PROGRAM

SET 1 QUESTIONS

4	3	6	5	1	6	1	9	9	7
+3	+6	+6	+1	+9	+3	+4	+6	+1	+2
0	1	7	5	8	3	5	9	1	8
+2	+3	+3	+2	+1	+4	+6	+5	+5	+3
2	4	7	8	6	8	2	1	0	9
+3	+5	+1	+4	+1	+0	+4	+2	+0	+4
1	2	3	5	8	0	5	0	4	5
+0	+6	+0	+7	+6	+3	+3	+7	+8	+0
2	6	0	2	4	7	6	4	7	3
+0	+2	+4	+5	+6	+7	+4	+4	+8	+9
7	3	8	1	6	9	1	3	4	8
+6	+3	+2	+6	+9	+0	+1	+7	+1	+5
4	0	8	4	9	6	3	3	5	7
+7	+1	+8	+0	+3	+7	+1	+8	+4	+9
9	2	1	3	1	7	7	2	2	6
+9	+7	+8	+2	+7	+5	+4	+8	+2	+5
5	4	0	2	9	0	7	0	9	5
+8	+2	+5	+9	+2	+9	+0	+8	+8	+9
2	0	8	6	6	9	4	8	5	3
+1	+6	+9	+8	+0	+7	+9	+7	+5	+5

SET 2 QUESTIONS

10	14	52	86	43	43	25	68	20	26
+19	+81	+37	+12	+22	+34	+53	+11	+13	+60
53	42	51	18	33	10	31	52	71	37
+40	+46	+11	+70	+41	+28	+57	+21	+24	+31
11	62	30	20	75	17	29	61	34	41
+52	+20	+66	+44	+12	+30	+70	+36	+25	+13

22	36	10	23	17	41	10	310	114	352
+32	+13	+45	+26	+62	+55	+519	+881	+437	+112
134	553	611	413	560	340	446	111	170	341
+743	+125	+168	+420	+426	+453	+242	+251	+818	+533
228	557	621	324	731	252	226	366	144	712
+510	+231	+252	+671	+237	+611	+462	+330	+520	+175
130	670	236	425	313	232	113	345	423	262
+317	+329	+761	+134	+241	+322	+636	+110	+526	+217
155	10	1	4	1	30	5	4	2	6
+441	+ 2	+18	+30	+50	+ 1	+61	+42	+83	+70
0	3	2	95	25	84	42	50	73	64
+27	+95	+5	+ 1	+ 4	+ 4	+ 4	+ 0	+ 3	+ 3
402	18	30	50	201	61	42	83	673	222
+ 10	+801	+304	+701	+ 30	+105	+904	+502	+ 6	+ 43

SET 3 QUESTIONS

76	11	24	89	17	45	39	38	68	59
+16	+29	+36	+11	+43	+26	+35	+53	+24	+14
25	18	64	44	57	86	77	43	37	28
+67	+76	+28	+36	+27	+14	+18	+49	+56	+72
36	13	28	44	68	19	36	53	27	79
+49	+77	+25	+47	+28	+83	+37	+18	+69	+19
27	17	62	36	45	32	719	679	835	148
+85	+64	+28	+55	+58	+59	+162	+328	+149	+629
556	269	274	188	335	426	801	714	639	507
+128	+417	+519	+717	+605	+226	+189	+166	+251	+383
345	459	278	178	194	253	585	646	241	477
+226	+335	+603	+814	+243	+676	+361	+283	+564	+472
360	171	135	478	383	361	132	284	447	286
+342	+683	+192	+161	+124	+295	+773	+255	+271	+181
398	462	26	41	34	59	47	15	79	3
+530	+374	+ 6	+ 9	+ 6	+ 1	+ 3	+ 6	+ 5	+98
4	4	7	6	8	6	274	63	175	31
+68	+99	+75	+28	+94	+84	+ 73	+446	+ 81	+399

276	981	60	503	18	254	268	89	6	3
+ 63	+ 24	+992	+ 27	+635	+ 7	+ 8	+503	+327	+918

SET 4 QUESTIONS

46	84	99	69	37	75	99	78	71	27
+76	+86	+36	+71	+83	+96	+95	+53	+49	+86
68	59	25	98	94	55	87	66	97	43
+54	+84	+97	+26	+88	+95	+97	+84	+78	+99
88	66	43	98	94	78	59	96	83	17
+72	+69	+67	+65	+17	+38	+63	+57	+38	+99
79	87	97	52	86	45	52	79	69	75
+69	+45	+44	+78	+65	+88	+59	+72	+48	+89
38	86	69	34	88	186	654	859	489	947
+99	+28	+97	+79	+57	+346	+246	+ 76	+161	+ 83
155	579	468	371	637	788	869	35	188	344
+656	+275	+243	+589	+296	+124	+ 94	+877	+756	+478
585	297	766	137	173	398	476	673	728	264
+285	+637	+ 74	+688	+299	+192	+359	+247	+185	+357
158	429	596	93	757	389	167	697	242	586
+788	+ 93	+327	+688	+199	+499	+785	+ 74	+498	+ 75
665	242	399	799	875	58	196	989	214	978
+368	+769	+662	+218	+139	+969	+858	+ 37	+799	+ 67
826	934	519	869	477	585	729	618	731	347
+446	+436	+756	+621	+813	+506	+755	+463	+849	+946

SET 5 QUESTIONS

14	26	15	25	42	40	53	10	20	18
27	15	19	13	12	72	15	17	31	30
21	14	17	28	19	51	10	18	20	21
+32	+37	+16	+37	+37	+68	+42	+23	+15	+30
11	99	91	12	39	72	15	18	12	82
19	23	23	22	24	52	46	19	93	46
26	29	37	87	64	41	21	53	33	17
+43	+57	+29	+69	+84	+72	+93	+43	+71	+26

325	501	151	513	364	440	512	907	260	102
713	197	192	105	187	123	126	125	163	407
125	215	436	103	120	416	324	137	521	167
+243	+269	+281	+314	+121	+804	+120	+503	+240	+105

17	41	54	14	34	47	22	21	42	16
21	77	90	15	10	32	61	12	15	60
32	19	29	12	17	10	34	45	72	70
23	87	63	27	63	19	39	37	53	29
44	81	24	12	20	63	70	84	19	54
+16	+14	+32	+14	+23	+14	+37	+16	+15	+59

15	72	48	72	14	47	58	41	10	40
92	16	17	38	44	14	16	91	13	55
61	39	26	92	31	52	72	73	23	90
34	81	16	15	29	53	83	92	20	80
12	17	29	32	63	73	73	41	19	10
+19	+28	+14	+13	+39	+16	+56	+17	+ 4	+43

90	15	53	15	752	50	82	55	72	46
63	204	61	28	10	903	1	3	85	37
101	10	705	1	799	13	99	7	6	52
13	1	47	100	33	405	3	8	93	105
12	536	63	50	829	66	46	503	70	6
+ 16	+ 27	+ 29	+ 3	+ 10	+707	+ 7	+ 12	+ 7	+ 8

826	647	84	63	72	17	25	1	42	25
6	85	16	7	5	25	31	33	605	125
51	728	204	8	6	26	49	133	7	52
458	99	37	9	9	502	652	3	50	2
19	647	48	408	858	19	71	31	80	50
+ 23	+ 82	+903	+ 3	+ 7	+ 20	+ 5	+100	+100	+150

63	51	53	72	77	27	6	17	22	294
23	325	150	308	84	4010	72	183	46	63
428	63	20	80	652	324	4032	29	93	208
6	7	6	406	82	6	148	468	24	84
508	429	808	12	10	93	63	7290	63	206
+ 7	+ 18	+ 12	+523	+108	27	999	406	42	42
					2216	2046	15	806	291
					+ 22	+ 12	+ 8	+ 71	+ 15

36	731	144	66	12	71	74	8	16	53
72	821	162	72	43	88	83	7	8	27
81	908	310	804	53	89	66	6	73	81
25	932	428	63	63	17	53	5	9	19
26	364	62	728	91	22	47	4	4	29
42	481	503	54	83	45	38	6	0	71
18	266	27	71	65	47	29	3	7	33
+19	+581	+819	+826	+63	+63	+11	+9	+ 8	+67

2192	219	97	426	54	92	54	628	54	1044
430	83	92	91	208	86	732	71	63	928
15	7	81	8621	63	104	16	813	77	2088
7	4862	365	51	12	25	85	24	187	2354
8	12	24	6	507	19	641	93	32	1007
26	346	16	12	84	91	72	105	54	1182
543	8	36	18	663	199	503	50	86	320
+3192	+ 99	+ 12	+ 19	+ 74	+2099	+ 27	+ 9	+104	+1011

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