Design considerations for a micro-computer system for computer-aided learning

PUBLISHER

Loughborough University of Technology

DESIGN CONSIDERATIONS

FOR A

MICRO-COMPUTER SYSTEM

FOR

COMPUTER AIDED LEARNING

by

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A Master's Dissertation submitted in
partial fulfilment of the requirements
for the award of the degree of
Master of Science in Mathematical
Education of the LOUGHBOROUGH
UNIVERSITY OF TECHNOLOGY,
October 1982.

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ABSTRACT.

This study considers factors in the design of computer systems for computer aided learning.

The development of computer aided learning from teaching machines and programmed learning is traced and a survey of contemporary activity in this field is made.

Those elements in learning theory which form the basis of a design philosophy are described. Features of the operating system, hardware and software are investigated for their effects on pedagogy. Special attention is paid to the user interface.

A possible solution to the problem of flexibility and software portability is described.

ACKNOWLEDGEMENTS.

I am indebted to my colleagues at Derby College of Further Education for many interesting discussions during the preparation of this dissertation. I would also like to thank all the colleagues in other educational institutions who have sent me programs to try and all the students who have tried them.

I am very grateful to Dr H.W.English for his help and encouragement and to S.Wardle for deciphering my handwriting and typing this study.

Finally, I would like to acknowledge the help and support I have received from my husband and family throughout this period.

Contents.

Chapter 1

Introduction.

A device which could provide the basis for a system for computer assisted learning was hypothesized in 1945 by Vannevar Bush. Bush called this device a "memex" and it was described by C.T.Meadow (1970) as an interactive information storage and retrieval system. A "memex" would be a personal device like a slide rule or a private library.

In 1945 computing was in its infancy and the technology available could not produce a "memex". Even, in 1970, a personal device such as this was barely achievable.

During the last decade, developments in both hardware and software have been such that the basis of a system for computer aided learning is now available. However, the design problem is perhaps greater than earlier writers, such as Meadows, envisaged. For, as Camstra (1977) wrote, "CAL has been in existence for over 15 years and yet the quality is poor."(CAMSTRA,p 178). Even so, the technological advances in the last few years have led to an even greater interest in Computer Aided Learning amongst students and teachers. Teachers have found that Computer Aided Learning can help with certain educational problems such as the call for more individualised learning (e.g. Lawton, 1973). Students seem more motivated to learn via a terminal than by other educational methods.

Currently, many definitions of computer aided learning exist and a number of different terms are used to describe educational processes which involve the use of computers. Similarly, computer systems assume many different forms and agreement on the meaning of the term 'computer system' is difficult to find. A precise definition of computer system is not as necessary to this discussion as a clear idea of computer aided learning. The computer system is that assemblage of hardware, software, operating system and environment which actively aids learning in a student within an educational institution. Thus the definition of 'computer system' is subservient to the definition of Computer Aided Learning.

Computer systems have been used in educational institutions in three main areas as P Lambert(1974) detailed at the Fourth Imperial College Conference on Computing in Schools:

"1. Education about computers

2. Computers as a resource in learning or teaching

3. Computers in administration " (LAMBERT,p1)

Within institutions of higher education, computers have also been used in a fourth area, that of research.

Education about Computers.

The choice of equipment for the first area was much discussed during the nineteen-seventies and depends very much on the level of education to be achieved.

Computers in Administration.

The needs of the third area are similiar to those of commercial data processing. Consequently the analysis of such systems has been exhaustive.

Computers as a resource.

The second section, which is called by Lambert, "computer based learning", has special needs. Some of the consequences of these needs may be also applicable to commercial computing but in education they are paramount.

The consequences of these needs for the design of a computer system is the subject of this discussion.

Many words have been written justifying or denigrating Computer Aided Learning. This study does not seek to add to that discussion but takes the use of computers within the educational institutions as a fact.

Consequently the definition of computer aided learning used is a very broad one. Computer aided learning is considered to be any learning activity by the student within an educational institution in which a computer system plays an important part. This definition includes simulation, games, guided discovery, programmed learning, drill and the use of data bases and packages. Record keeping is included where this is a necessary part of course selection and pacing but administrative tasks such as time tabling, room allocation and general student records are not considered.

Learning at home with the aid of a computer terminal or personal computer may well become an important part of an individual's education. Already, for many severely disabled students computer systems can provide means of communication and home education which would not otherwise be possible. However, most existing educational software is designed to be used within an educational institution and furthermore, the home as a computing environment has implications for hardware design. Consequently computer assisted learning is investigated within educational institutions in general and within secondary schools and colleges of further education in particular.

This definition must be broad for the systems design to meet the expectations of computer aided learning; expectations which increase year by year. On the other hand, if too broad a definition is used, the concept becomes too vague and design becomes difficult. It has often been the complaint of technologists that educationalists have been insufficiently specific.

This study seeks to look at the development of Computer Aided Learning and at the often interrelated development of learning theory in recent years, in order to suggest an incorporation of current tachnology which can best support and continue the present enthusiasm.

Chapter 2

The Development of Computer Assisted Learning.

Early Developments.

Educational technology has a long history. Mechanical devices for teaching spelling and arithmetic existed during the nineteenth century. A machine for administering the birch is depicted in a sixteenth century woodcut. The real beginnings of computer assisted learning came with the development of programmed learning devices by Pressey (1960) from 1912 onwards. The first public report of this early learning system was made in 1926. Despite the efficacy of Pressey's methods, interest in programmed learning was not aroused for another two decades.

During the nineteen-fifties, the work of Skinner (1968) and his associates gave rise to new learning theories which emphasised the importance of feedback and reward.

The programs of learning that were developed often presented to students, concepts that at first they did not understand. However, after being guided through many small steps, they began to generalise from the particular. The correct response to every question was obtained from the student before the program continued. The student gained instant feedback as to the correctness of his/her response.

By 1961 the American Forces were reporting much success from courses designed along Skinnerian lines. They claimed, in particular, that programmed learning reduced the time taken to reach a particular level of skill. The greater cost of programmed learning was offset by greater efficiency in the use of student time.

Enthusiasts for programmed learning like Margulies were predicting in 1962 that by the middle of that decade "most systematic teaching in U S schools and colleges will be done by teaching machines and programmed text books"(Margulies and Eigen,1962,p288).

The courses provided by both machines and text books could be branching. In fact an eminent practitioner (G M Leith) declared that "machines at the present stage of development have not demonstrated advantage over text book presentation of programmes"(Leith, 1964, p 71). He continues however, "It remains to be seen whether the addition of audio-visual equipment which could not be employed by a simple text or the use of individual computerised adaptive machines (both somewhat more expensive) will be more effective and economically flexible."

Margulies agreed that computer based systems were unlikely to make education less expensive but stated firmly that they should make it more effective. He was so certain of the growth of computer based systems from this point in time (1962) that he predicted that a hundred million dollar a year market would exist for the next ten years. His specification for a teaching machine consists of five elements - a data storage receptacle for the materials to be presented, a display mechanism, a response panel and a feedback mechanism.

This specification was met by both mechanical and computerised devices. An example of the latter was the Benedix G-15 computer. This machine had its teaching programs stored on paper tape, a random access slide projector holding 600 slides and a typewriter. Its controlling program was capable of branching,skipping sections and providing remedial help from an alternate series of frames. It also had a simulation facility.

Programmed learning did not become as important in the UK as in the USA. A considerable amount of work was undertaken at some universities such as London (Birkbeck) and Newcastle, and a BBC programme urged the use of programmed learning for such purposes as teaching of basic skills, levelling, enrichment, remedial teaching and ancillary skills (e.g. use of logarithm tables and slide rules).

Progress was held up by the large investment of effort required for the writing of good programs, and the lack of teachers trained to write them; the expense of building attractive teaching machines and the cost of producing computerised systems.

Although protagonists demonstrated the gains to be made by use of programmed learning, these were not in general felt to be sufficient to justify the investment required.

The introduction of computers into educational establishments during the latter part of the sixties and early seventies (for use in conjunction with research and computer appreciation courses) however, led to renewed efforts to use part of their time for CAL.

The National Development Program in Computer Assisted Learning.

Eventually, in 1972, the Government decided to set up an investigation into CAL. The National Development Programme provided background organisation and philosophy. The Programme was provided with £2M to spend over five years and, with R Harper as Director, commenced work in January 1973. The main remit of the Programme was to study the application of computers in education in the areas of further education, schools, the armed services and industry.

In January 1973, the main aim was defined as "to develop and secure the assimilation of computer assisted and computer managed learning on a regular institutional basis at reasonable cost". To which was added, in 1974, an aim "to make recommendations to appropriate agencies in public and private sectors concerning possible future levels and types of investment in computer aided and computer managed learning in education and training".(NDPCAL, 1975).

Realising that CAL could not be just tacked onto the existing educational garment, Hooper decided that the project's activities would follow three main lines. They would:

1. identify the place of CAL within the curriculum;
2. investigate the place of computers alongside other media;
3. develop viable organisational structures to support CAL

At the commencement of the National Programme much concern was expressed over the need for transferability of any materials developed. As a result programs had to be written in Fortran or in the NDPCAL's subset of BASIC.

Some seventeen projects were set up. By 1972 Hooper reported no judgements but some generalised assertions:

(a) that computers in education are here to stay;

(b) that not all uses of the computer in education will spread equally fast;

(c) the uses of computers will not spread evenly across all disciplines and sectors;

(d) the introduction will be most quick when it is "piggyback" on computing facilities;

(e) computer costs must be added onto other costs;

(f) eventually the terms CAL, CML will become obsolete as computers come to perform a variety of sub-functions within education.

Projects set up by NDPCAL ranged from Remedial Reading schemes in Glamorgan via secondary education in Hertfordshire to many projects in higher education. The emphasis on higher education was brought about by the decision not to fund hardware but to buy time and research effort. In deed with the amount of money available to NDPCAL it would have been difficult to do anything else. Institutions which had their own facilities were therefore the sites for most of the research.

The Final Report of the Director(Hooper 1977) emphasises that CAL and CML have come to stay and that this must be recognised by educationalists so that the process becomes properly institutionalised. Computer costs are seen as likely to increase rather than decrease educational expenditure although savings may be made in laboratory costs. Very little mention is made of the technology itself in any of NDPCAL's reports. The entire effort seems to be expended on provision of teaching materials and little mention is made even in the case studies of the effect of the interaction between student and machine. In looking to the future, a mention is made of minicomputers but no real consideration of the effects of technological development is apparent.

Technological development in the Seventies.

During the years of deliberation by NDPCAL, considerable technological advances had taken place which were important to the development of Computer Aided Learning.

The advances of greatest importance to CAL were the increasing scale of LSI and the arrival of cheap backing store in the form of floppy discs.

The advent of LSI and later VLSI had itself three consequences;

(i) memory became cheaper;

(ii) more and more components were developed so that a whole formation of a system could be contained in one package, e.g. an A/D converter;

(iii) the advent of "softwired" logic in the form of the microprocessor.

By the mid-seventies, the availability of "naked minis" at the £300 mark led many technically qualified teachers to take this way of providing their school with a computer. In most cases these machines were constructed to provide support for Computer Studies/ Science/Appreciation courses rather than for Computer Assisted Learning.

As these machines were the result of individual initiative and expertise they were not standard equipment.

The consequences of this were serious. Amongst the most important results were the amount of time which the teacher had to devote to maintainance the unavailability of compatible software and probably the most serious, the difficulty experienced by the school in using the equipment once its constructor left the school. The last mentioned consequence was exacerbated by the high mobility of teachers at this time.

The Berkshire Working Party.

Against this background a conference was held at Bulmershe College of Higher Education in 1976 to consider the effects of the microprocessor on Computer Education. The conference set up the Berkshire Working Party (of which the author was a member) to:

a) investigate what was available;
b) discuss what was necessary in a computer system designed to support computer studies;
c) recommend a best buy in an effort to standardise.

Our discussions were aimed at providing schools with a cheap and reliable machine for use with computer studies courses. The designers of what became the Research Machines380Z microcomputer were involved in the working party.

In 1976 most computer studies syllabuses involved a considerable amount of programming. Very few schools possessed their own main frame or mini computer because the systems were prohibitively expensive and also, in the case of main frame machines, required special environmental provision. Pupil's programs were usually processed by the computer departments of the local authority or local industrial concerns. In some cases the programs were batch-processed and in other cases access was given via a tele printer terminal. Batch processing worked well if the turn round time was good i.e. within one week but pupil's work had low priority and consequently turn round times were often much longer.

Access via terminal was better in that it provided the thrills of 'hands on' experience but even the best typist in the class at this age tends to be quite slow. The entering of even a short program takes quite a long time. The problem was exacerbated by the slowness of the terminals and by system requirements. One wellknown system at this time required that no less than six characters (some non-printing) in the correct order must separate each line of print.

The final report of the Working Party which was published by the National Council for Educational Technology in Micro computers in Education(ed D Sledge pp 35-36) must be read with this background in mind. The system proposed was to be simple and robust in operation and, to utilise as periperals devices which were already possessed by most schools. It consisted of:

(i) a key board and a box containing the CPU which would be bought from the manufacturer

(ii) a cassette player and a black and white television which the school would probably already possess.

(iii) and system software on cassette which would be bought from the manufacturers.

This simple system was adequate to support computer studies practical work as it was conceived at the time. The use of the system for computer aided learning was not considered by the working party.

However, when Berkshire County Council decided to put RML 380Zs into their schools on a half-funded basis, teachers in those schools looked forward to using them for computer assisted learning.

Other Developments.

At this period a number of other education authorities had schemes for using computers in schools. Amongst these authorities, Hertfordshire and Birmingham can be taken as examples of the type of provision available.

Birmingham offered two types of access to computer equipment. Schools could have a terminal and on line access to a central machine. In addition, working parties of interested teachers, under the guidance of an electronics expert, constructed micro-computers from kits which were based on the Motorola 6800 micro-processor. The education authority employed teachers centrally to support the work in schools.

Hertfordshire organised computing in schools via a centre at Hatfield Polytechnic. This centre housed a large computer system which was used to support computer studies and computer appreciation courses. A considerable amount of effort was put into development of computer assisted learning packages. For instance, the development of a computer managed system for teaching mixed ability mathematics in the first two years of the comprehensive school was one of the projects funded by NDPCAL. This system provided individualised worksheets to back up live teaching and the use of video taped materials.

The 'MENU' program illustrates another way in which a computer was used to assist teaching. This program analyses the nutritional content of foodstuffs and also the dietary needs of individuals of various ages and conditions. Thus it provides support to biology, cookery and nutrition courses.

Contemporary Developments.

Throughout the seventies computer assisted learning continued to grow. The growth was much slower than had been expected for two main reasons; the unsuitability of the computer systems for educational purposes and the lack of institutional support for the new technique.

More suitable equipment began to emerge at the end of the decade and its incorporation is discussed later.

Recently institutional support has increased rapidly. This increase can perhaps be dated from a television program "The Silicon Factor", in 1981. Although it could be said that the television program acted as a catalyst drawing the public's attention to the new technology. The addition of public pressure to the private urgings of those involved in computers in education at last produced official action.

The contemporary scene can be described as one of feverish activity. At a time of cut back and recession, money has been made available for curriculum development in this area.

There are two main prongs in the national attack. In addition, of course, a vast amount of interest exists within schools.

Firstly 'The Microcomputer in Schools Scheme' sponsored by Department of Industry provides a method whereby a school can equip itself with a system more sophisticated than that proposed by the Bulmershe Working Party in 1979. The system is available at a special price of which the school pays half and the remainder comes from central funds. The equipment consists of a micro-computer with twin mini floppy discs and 48K of store and high resolution graphics.

Secondly, a sum of five million (initially) has been set aside for projects in computer education under the auspices of the Micro-electronics Education Project. This project is serviced by the Centre for Educational Technology. The Director of the Project, Richard Fothergill, and his staff have delineated four areas in which development is to be persued. These can be broadly summarised as:

1. Computer Literacy and Control Technology
2. Teacher Training
3. Informantics
4. Special Education.

A number of projects have been funded in these areas. Some of these are continuations of schemes already in being; e.g. Chelsea College Computers in the Curriculum Project and others are new; e.g. Telesoftware.

Each of the four areas listed above is capable of absorbing all the money available for the whole project and of producing a vast amount of information which needs to be desseminated. Regional Information Centres have been set up to communicate results and to coordinate activities at a local level. The Micro-electronics Education Project has decided that on the limited amount of money available, a "cascade" model of dessemination is best.

Information is to pour from the Project through the Regional Centres to the local education authorities which form each region. The advisory service of each authority will then pass the information on to the schools and thence to the classroom teacher.

To quote J Megarry in 'The Times Educational Supplement' on 27 November 1981 "If it works well, this model could provide cost effective transmission of a most exciting message. However, as with all indirect means of communication, there is some potential for the message to become distorted in the transmission."

The length of the 'cascade' is considerable and this is likely to lead to problems. It is difficult to see, in a 'cascade' model, a method of providing a path for information to flow back from the classroom to the Centre or to other regions.

However, even allowing for doubts and difficulties, there can be no doubt that considerable resources are being expended on computers in education at the present time. It is possible that educational computing is just another educational fashion. It has been suggested by Schure (1970) for instance, that programmed learning has failed and that computer assisted learning will similiarly fail. Whilst opinions may differ about this, such a failure seems unlikely for the following reasons:

1. Programmed learning grew out of a theory of learning which has not transferred well from laboratory animals to humans. Learning theory has progressed in the last thirty years.
2. Computer aided learning enables learning to take place in other ways than does programmed learning.

The current emphasis in CAL are on simulation, problem solving and the use of data bases.

3. It seems at present at least that students enjoy using CAL systems: that the use of the system is in some way motivating (Carpenter 1970).

4. We must educate better and more effectively. As Garry and Kingsley observe "our annual convoy type of education and our ability to manage attitudinal social and conceptional learning are most uncertain and haphazard. The spoilage rate of 25-30 percent is excessive". These authors believe that "we are approaching the point where we possess the technological and scientific and social skill to remedy the matter" (Garry and Kingsley, 1970, p 281).

Chapter 3

Learning theories and computer assisted learning.

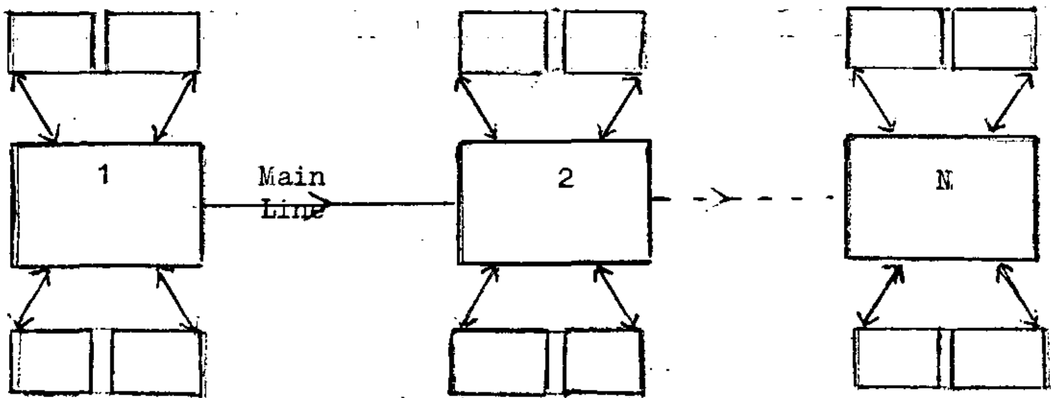
It is essential that if computer assisted learning is to bear fruit, systems should be designed that incorporate the best of current educational theory. Learning theory patantly has a long way to go before its models are as adequate as those for, say, theoretical physics. However, if we take our present state of knowledge as a starting point, a system should be designed which at least does not contradict that knowledge.

A system for computer assisted learning will alter as computer technology advances and it will also need to alter as advances are made in learning theory.

The connexion between the learning theories of B.F.Skinner(1968) and the development of programmed learning has already been described Skinner emphasized the importance of immediate reinforcement in learning. He designed his programs so that the possibility of a wrong response was minimised. The programs were linear with constructed responses. Skinner claimed that machines were essential to ensure immediate response for each student. "The simple fact is that, as a mere reinforcing mechanism, the teacher is out of date," he wrote. He was concerned that each individual's learning should be reinforced yet it is probably the lack of individualisation possible in his program that has led to the failure of programmed learning.

A different approach to programmed learning which made more allowance for individual learning styles has been developed by N.A.Crowder (1960).

He considered that one theory such as Skinner's could not completely account for human learning. He suspected that human learning takes place in a number of ways and that this variety interacts with different environments. Crowder attempted to deal with this variability by constructing branching programs. The diagram below shows the layout of such a program. If a student has difficulty with the main line then he makes an excursion and then returns to the main line.



Diag. No. 3.1

There are many possible paths through the program. One possibility is the student who goes straight down the main line. Another possibility is a student who makes all possible errors. In this way Crowder allows for individual differences in learning. Crowder did not have a specific learning theory but maintained the importance of accomodating individual differences in learning.

One can trace a growth of importance of the concept of individual differences within learning theory. For instance, Piaget's experiments in support of his developmental theories indicated the very different rates at which individuals pass through the stages of intellectual maturity be delineated. Solomon (1980) writes that media have different effects on each individual also that concepts are conveyed differently to the human mind by the different media. So that, if one learnt a piece of mathematics by watching a film, one might structure the concepts in one way. If however, one had learnt the same piece of mathematics from a book then the mental structure would be different. The difficulty lies in designing a system which will deal with all factors in a situation as complex as this.

There are however a number of discoveries and theories which provide useful starting points for system design.

A Curriculum Design Model.

Firstly, it is possible to combine the theoretical base of the curriculum development work of Bruner (1966) with the pre-learning structures favoured by Ausubel (1968) to produce a curriculum design model that is both familiar to teachers and useable by programmers. Its familiarity to teachers will mean that computer-assisted learning programs can be readily integrated into existing teaching schemes and thus be easily incorporated into existing educational structures.

Structured Concepts.

Secondly, recent research (such as that be Simon (1979) and Pask (1975)) has indicated the importance incorporating learning into mental structures. If information is not so incorporated then it will not subsequently be available to the individual.

This knowledge has come from the already extensive use of computers to learn about human learning. Newell and Simon's (1962) work in the fifties with the logic theory program is an early example of such research. One particularly useful idea which has resulted from the work of Simon et al is the concept of the "chunk". The "chunk" is the maximum number of items that can be held in short term memory at once. This number varies between individuals (between 3 and 7) but 5 items seems to be the modal value.

The size of the individual item however depends on the ability of the individual to structure them. For instance, if a grandmaster is asked to replicate the placing of pieces on a chessboard, which he has seen for a short time only, he will succeed if the position shown represents an actual game situation. If it does not, the grandmaster will do no better than a chess novice (i.e. each of them will place approximately 5 pieces correctly).

Items of information then, will pass from the short term memory to the long term memory. The ability of an individual to recover items from long term memory seems to depend on the number of routes to them, i.e. upon the mental structures that the individual builds.

One implication of this research for constructors of computer aided learning programs is the necessity for careful structuring of the material.

Another is an indication of a solution to a problem whose existence is only just being realised. Knowledge is no longer mediated only through teachers and books but it is made available to modern students in many ways. R.M.Gagne (1977) accuses teachers of failing to recognise that children watch television. He claims that this failure to incorporate the information thus gained into school curriculum leaves the children with constructured concepts. However the wide variety and large amount of such information makes the structuring a difficult task for the teachers.

With the aid of computerised database, the teacher may well be able to help children to build useful mental structures out of the mass of information which surrounds them.

Teacher/pupil Relationships.

Methods of structuring knowledge vary from individual to individual. The existence of this variation is, according to R.R.Skemp (1979), an impediment to the learning process even in a learning situation of one learner per teacher.

Skemp visualises the intellectual process of teaching and learning like this:

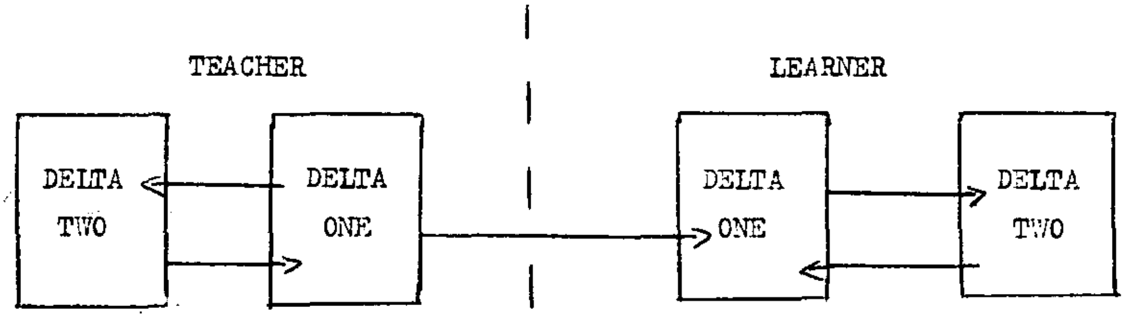


Diagram No 3.2.

Model of Relationship between Director Systems of Teacher and Student

The delta-one director systems are directly teachable. The delta-two director system operates on the delta-one system but is not directly teachable. Emotions affect the operation of both. The systems of both teacher and pupil contain a model of the other. If the models are not correct then learning will be ineffecient. If the models are good then a cooperative relationship can be established.

Skemp claims that many of the stresses present in teacher / pupil relationships can be predicted from his model.

The existence of these strains is well documented. For example the effect of teacher expectation on pupil performance (which is just one such barrier to learning) is delineated in such works as Staines' "The Self picture as a Factor in the Classroom" (1958) and also in many studies on the practice of streaming such as those undertaken by Jackson (1964) Pidgeon (1970) Stevens (1972) and Ferri (1973).

The researches of Bijou (1969) and Richardson (1973) into the promotion of good learning environments are also relevant.

These problems in teacher / pupil relationships provide a third body of knowledge with important implications for Computer Assisted Learning because as Lumsdaine and Glaser (1960) observed students like teaching machines because they perceive them as neutral. They wrote "Failing students frequently rationalise their difficulties by charging that the teacher does not like them. A machine has no likes or dislikes, no class consciousness, no racial prejudice" (1960, p 413). These observations have been confirmed outside the educational field by some research by Lucas (1977). He found that patients respond more accurately and with less anxiety to questioning about symptoms from a computer terminal than from a doctor. The research team considered that the use of the terminal reduced feelings of embarrassement caused by factors such as differences in social class, education and authority between doctor and patient. It is worth noting that great care was taken with the design of the dialogue in this case.

A cautionary note must be sounded, however because a teaching system cannot be completely neutral. This is because a program author does not write blindly but with a target audience in mind. However it may be true to say that interactions at the terminal do not threaten a student's inner reality in the way that Skemp claims that interaction with a teacher may.

The specifics of dialogue design are discussed later in Chapter 4. However it is obvious from the above that an approach to the problem should be made along the lines of the ZOG philosophy as described by Robertson, McCracken and Newell (1981). ZOG does not stand for anything but it is short, easily pronounced and remembered. The design philosophy seeks to provide a transparent device which has no intelligence but is immensely responsive to the user.

Cognitive Style.

The fourth area of educational theory with important implications for Computer Assisted Learning is cognitive style or learning strategies. Sufficient evidence has been accumulated over the past forty years for the existence of various learning strategies. However, according to Pask (1975) under free learning conditions most students have difficulty in selecting an appropriate strategy. This may be due to lack of knowledge of suitable strategies. Performance is improved ny imposing a well defined strategy. It seems to make little difference which strategy is chosen although one which matches that of the student will lead to most efficient learning.

This is, of course, an area which computers have been extensively used to aid research. Simon (1970) has tried to look for a general strategy of learning with the 'General Problem Solver'. Other researches such as Slagle (1963) have looked at strategies for problem solving in particular areas such as calculus and geometry. The programs which they have devised have selected or rejected strategies as they neared or deviated from the goal. It is hoped that these researches will provide more exact models of human learning. This will make the design specification for a Computer Assisted Learning package much easier to write. Authors such as Feigenbraum and Feldman (1963) have questioned whether the present state of knowledge is sufficient for the production of adequate CAL packages. They wrote in "Computers and Thought" (1963) "Do we know enough about cognitive styles or are software problems merely reflections of educational problems and ignorance?" (p.3.)

These two authors consider that recognition of cognitive styles is merely one of pattern recognition and that it would not be difficult for the computer to analyse a student's style from the data supplied by responses to lessons. Subsequent lessons could be altered in response to this analysis.

The problem that remains is the identification of the problems so that the system can detect them.

A well designed computer aided learning system contains within itself the solution to this 'chicken and egg' problem. As students work through programs an immense amount of data can be collected on their responses, successes and failures. The analysis of this data should identify the required patterns. Programs can then be revised along the lines of this new knowledge. Some educationalists consider that this ability to collect data will be Computer Assisted Learning's greatest contribution to education.

Milner and Wildberger (1977) wrote that "a comprehensive system would have the capability to generate problems, derive solutions thereto, compare student proposed solutions and generate remediation. The computer can provide a single point of contact through which instruction can be delivered, modified, managed and, most importantly controlled by the student" (p 122).

Such a system is at present beyond our capabilities for we lack both technology and educational knowledge. The four areas outlined above a basis for the design of a system which will not gainsay our present knowledge and will contain within it the seeds which may develop into Milner and Wildberger's system.

Chapter 4.

Operating Systems.

General considerations.

In chapter 1 computer assisted learning was considered as taking place within educational institutions. As D.Lawton (1973) points out, within the United Kingdom's decentralised education system, "every teacher is, to some extent his own curriculum planner", (Lawton 1973 p 8). Consequently if computer assisted learning is to form an important part of school curriculum then teachers and the educational environment must form part of the systems design. This is in line with curriculum models of Wheeler (1967), Kerr (1968) and Lawton (1973).

Fears have been expressed that the inclusion of computer-assisted learning within educational institutions could warp those institutions. For instance, F.J.Dahl (1970) wrote that "to provide intellectual elbow room within computer assisted learning will be the education's greatest challenge" (p 227). He considered that without this, computer assisted instruction would not be educationally good for the child as the child would quickly learn that only restricted modes of expression were possible. This would result in a debasement of education.

Whilst such a result is possible it is only likely to happen if computer assisted learning is used only for programmed learning type application and if students receive a large amount of instruction via a computer system. A similiar amount of distortion could result from over emphasis on any facet of the curriculum.

However the fears of Dahl and others can be avoided if the computer system is designed to fit current educational theory and practice. Curriculum developments which are consequent on the use of the system can then be designed using the curriculum models mentioned above.

If subsequent developments alter the education system then these alterations will be the result of the growth of educational theory and of teacher experience.

In addition to fitting current educational theory and practice, the computer system must also be flexible enough to adapt to progress both in educational theory and computer technology.

The final important principle for CAL systems enunciated by R Fothergill, Director of MEP, at a recent conference, "Computer based learning programs are about children learning not about learning about the computer system"(1981). In other words the computer system must assist the learner in his task not act as a barrier. At the very least it should be neutral. This is a demand which is not made of systems designed for commercial purposes.

The difficulties of designing an automated teaching system were well described by Roe, Lyman and Moon (1960,p 129) "it is possible to conceive such a system in too small or too large a scale. If the aim is too narrow, then the process is tedious for both teacher and learner. If on the other hand, one conceives of a system which will make precise evaluation of a host of variables which may be influencing the system, then the size complexity and cost of the computer element of such a system may be beyond the realm of practicability".

The aim therefore must be to specify as clearly as possible the educational matters so that the implications for the technology can be discerned.

(3) Specific uses of the computer system.

The use of computers to aid learning can be divided into four areas :

(a) Programmed Learning. This is sometimes called drill but I include branching programs and also remedial and reinforcement exercises.

(b) Structured problem solving and the so-called Socratic teachers.

(c) Simulations.

(d) Use of computer based resources, i.e. data bases, statistical and numerical analysis packages.

These areas overlap but they do make different demands on the system. In addition, one can conceive of programs of type (a) being used in a different environment from the others.

There are two physical environments within further education in which I envisage students using computers. Firstly, the computer system can be used like a book, as aresource in the sort of study room provided in many libraries, by a student who has missed a lecture or has a deficiency in some general area. Secondly, the computer system can be used by students in a Computer Resource Area where some technical assistance and educational assistance is available.

The first environment places special constraints on both software and hardware. These constraints will be discussed later on page 59

The User Interface.

Shackel (1979) writing generally, states that "For the user of today's computing systems, the terminal is, pragmatically speaking, the computer"(p 4).

The most important consideration for any user is the man/machine interface. As earlier remarks indicate, a system for computer aided learning is far from being the exception to this.

The design of the interface inevitably has consequences for other parts of the system. Details of these consequences will be considered later when software and hardware are considered in chapters 5 and 6. The present concern is general principles.

In the recent past the user has been forced by the designer of the computer to accept certain constraints on his behaviour. It was agreed that this was necessary because the hardware was strictly limited in its performance.

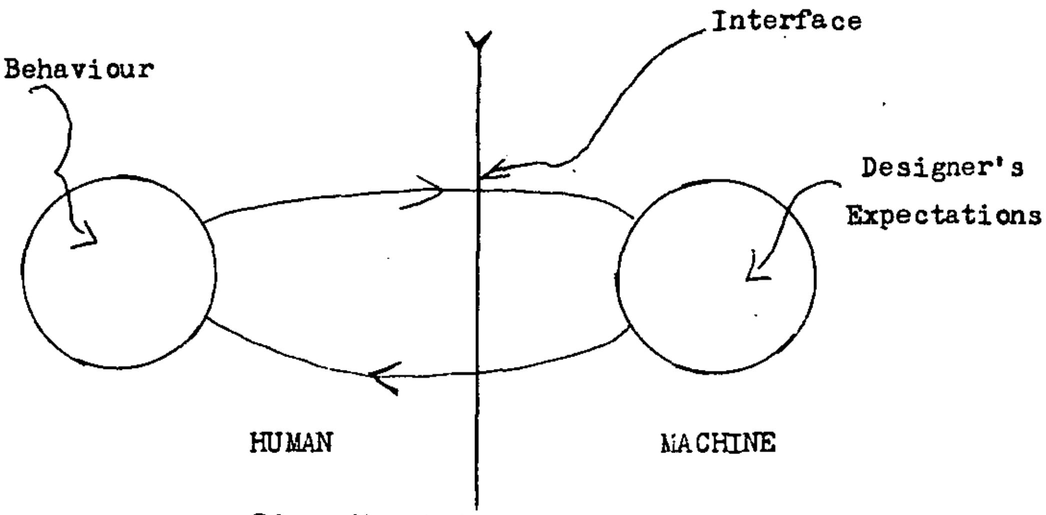
An immediately understandable message took far more time to print on the slow terminals then in use than did two or three digit error code. In addition such a message required more storage space and consequently the operating system occupied more of the expensive core store then in use.

A user therefore was required to take a manual with him to the terminal in order that he could interpret the error codes.

"This assumption", says E B James (1981) "underlies the design of all software, so calling for the absolute minimum of hardware use". (1981, p 338). He also claims that existing methods were designed for batch systems use and that interactive use via a terminal has been grafted onto that system. The traces of this design approach can still be seen in the operating systems of microprocessors.

Even when the system is sold as suitable for novices, the initial outputs are only interpretable by experts. One system, for example, informs of the number of the operating system and another how many bytes are free. (They also inform you of the name of the manufacturer which is emblazoned over the hardware.) There are occasions when these are very necessary pieces of information to have but neither are useful to the student needing to run a CAL program.

One can visualise the user interface in a number of ways. The first diagram is adapted from a fecent conference on Methodology of Interaction (Guedj 1980, p 50).



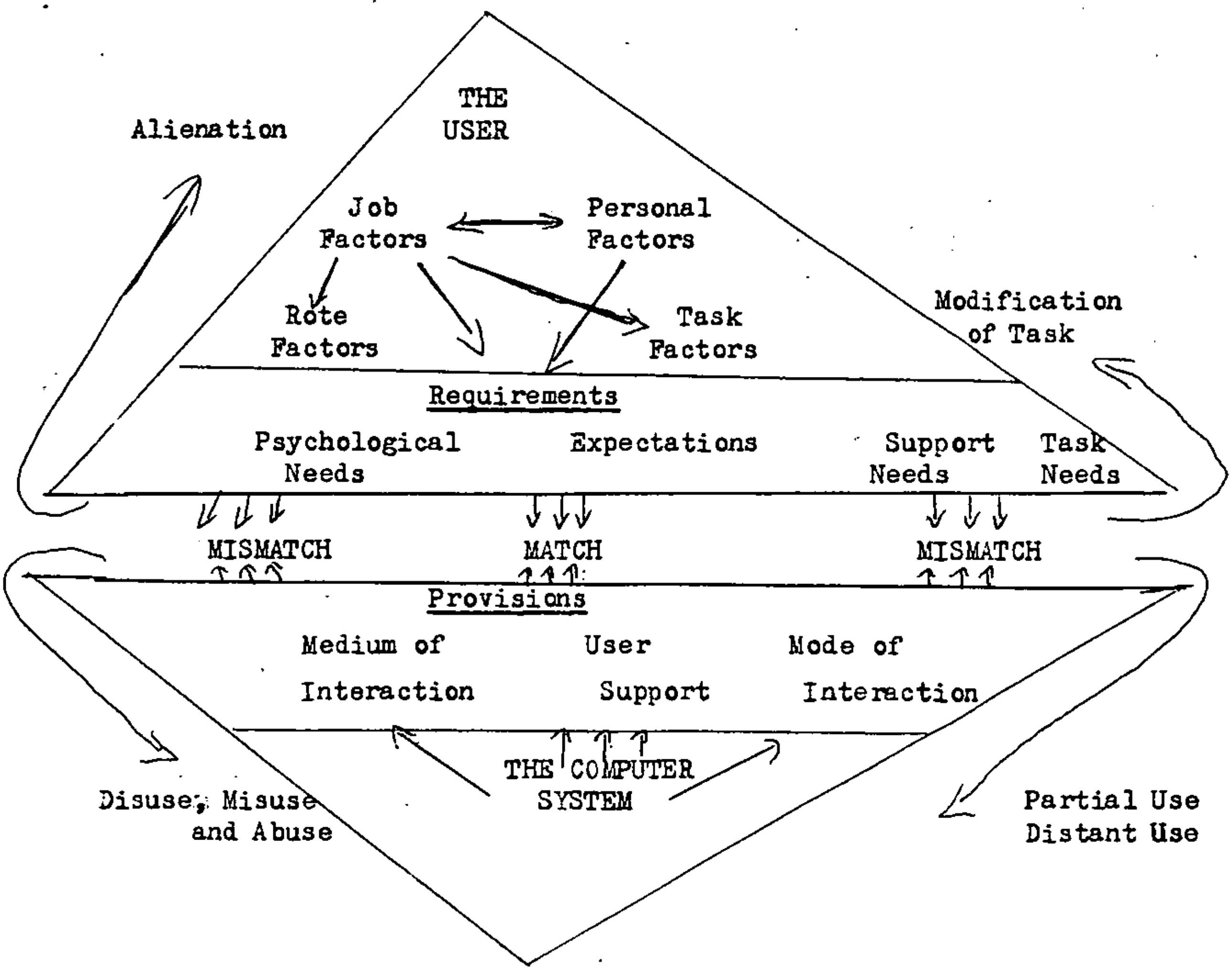
Diag. No. 4.1.
INTERACTION

Here the left hand space represents the man who brings certain expectations and behavioural patterns to the task. The right hand space denotes the machine which has certain capabilities and also has its designers' interpretation of the task inbuilt. "The communication across the interface has the goal of achieving agreement (congruence) between the parties as to respective behaviours to be invoked"(R M Bunn,1980,p 50), in order that the goal should be reached and the problem solved.

This underlines the point that human and machine are partners in the interaction. This model is in fact a very sophisticated one in that both human and computers are seen as building their individual constraints of the user's needs. So the computer is an active partner not just a passive one - reacting to commands from the keyboard.

Many CAL System proposals seem to call for operating systems of this sophistication. However, as Fine remarked in 1972 when designing TICCIT,"such a system is not yet achievable". (Although recent work on Artificial Intelligence by Pask (1975 (b)) suggests that it may be not too far away).

The second model proposed by Eason and Damodaran in 1981 is perhaps of more use at the current time (Coombs and Alty p 116).



The user, in this case the student or teacher, is concerned to perform his task, to continue with his studies, not to learn about computers. The system, therefore, must be reliable, adaptable, self-sufficient and easy to use. There are two aspects of the user interface that must be considered with these models in mind, The hardware interface - the machines usually used by the student, and the software interface - the controller of the machines and the producer of dialogue.

Dialogue Design.

Dialogue design needs to take into account a number of factors. It will be more efficient if it models human modes of thought and communication. As Glik and Weinburg wrote in Humanised Input (1977), "It is not surprising that computer input systems which fail to make use of natural defaults often force their users to feel ill at ease, for they must behave in a manner that would amoung humans indicate social awareness if not mental problems"(p.28.) This is not an argument for completely using natural language for man/machine communication. A great deal of work has been done in this field but without a great deal of success. To permit the dialogue to take this form, even if it could be done, carries too great an overhead of storage and computation time.

Shackel (1979) suggests a compromise, a solution which would reduce the ambiguity and difficulties of natural language and yet avoid the problem of the user having to acquire an artificial language. He quotes a study by Kelly and Chaponis (1979) which found that pairs of subjects undertaking problem solving tasks did no worse if restricted to a specific vocabulary of 300 words than did those who worked without this limitation. He goes on to suggest the possibility of deriving a restricted vocabulary and syntax which is easier on the computer but not as limiting to the human as the present system. Work by Addis, Boston and Underwood (1970) has already established the feasability of such a scheme.

As James (1981) writes, "people communicate best when they share a common language"(p 337). A computer user should not be forced into specialised jargon, neither should he have to go into further detail than is necessary for the job in hand. These details would only make the message less understandable.

Stewart (1979) suggests some useful guidelines for the design of dialogues of which the first is "start simple". This could be usefully incorporated into operating systems for use in schools.

The Operating System.

In many institutions the same system will have to perform many tasks. The system on switch-on could first determine for which use it was required. As the demands of a computer science student engaged in a project are more unpredictable than those of a student using a CAL package, it is reasonable to expect the former to supply more details to the machine. Once the universe of the dialogue has been established, then both parties can begin to communicate.

The operating system must attempt to interpret the user's instructions positively. The user's inputs should be used where possible. In addition, good ordering can lessen the inappropriate responses from the system caused by the fact that the computer does not (and, at present, cannot) share the vast knowledge of the world that even a small child has. Consider this example taken from Stewart's article:

1. NAME? FIONA
   SEX?

2. SEX? FEMALE
   NAME? FIONA

The second dialogue reads more naturally because one cannot infer a person's name from their sex but it is possible for a human to do the converse.

In the start up dialogue the initiative should come from the computer. All users will be new users at some time. However, the system should be flexible so that a user who knows what to do can skip what might otherwise be a tedious conversation.

Interpretation of user responses should be along the lines of this model suggested by Gilb and Weinburg for use with direct entry of records (diag p.91,1977)

"Do you mean " " "

"At this stage I need 1 of these commands "

Finally "Ask for help "

Behind the helpful dialogue must lie an operating system capable of coping with the considerable demands of Computer Aided Learning.

Many computers used for educational purposes, particularly for computer appreciation or computer studies, have been selected because one simply switches on and immediately is in the correct environment. That is the operating system and BASIC are loaded. With other more complex systems one may have to load a disc operating system, give instructions about other peripherals and load BASIC from disc.

The ease of operation of the simpler computer is frequently more apparent than real. For instance with one popular make of computer, to write to the printer it is necessary to open a file with a logical file name and a device name. If this file is not properly closed then the presence of an open channel to the printer affects subsequent operation of the computer. One might argue that in CAL situations where users are merely loading and running already prepared programs this would not matter. However, if a program crashes for any reason then the files will not be closed on the exit from the program. Even well written and tested programs can crash if a student makes a response which can be misinterpreted by the system. On the system mentioned earlier pressing only the return key when requested to input from the keyboard causes control to exit from the program and return to the BASIC interpreter. So a program which would run well in most other versions of BASIC will crash on this particular system.

As discussed later (p53) CAL programs tend not to require large amounts of hard copy. However, some access to a printer is required and similarly access to disc may also be required. On the system mentioned above one is encouraged by the manufacturer to link more than one machine to a printer or disc unit.

Unfortunately the use of IEEE bus as a connection device creates physical constraints and leaves the entire system vulnerable to one user switching his machine off at an untimely moment.

The manufacturer defends his system on grounds of cost and claims that all malfunctions are due to operator error.

In CAL systems the emphasis must be not on users needing to operate carefully in order to meet the system's requirements but on systems which attempt to operate to the user's requirements.

If an operating system is to be designed to meet educational requirements it is essential, as Eason et al (1980) suggest, that the user, that is, the classroom teacher, should be consulted during the design process. Matters which seem trivial to the manufacturer can loom large in the day to day drama of classroom life.

For instance, if a user has one machine which is switched on once per day - which is quite common with microcomputers used in small businesses, doctors' surgeries, etc - then one can tolerate a fairly large number of times that the data transferred from ROM to RAM on power up is transferred incorrectly because of poor checking procedures.

If, however, one has eighteen machines used for CAL in a room which are likely to be switched on at least once an hour throughout a nine hour day, then the chance of a misread on any one machine is much greater.

(In the computer studies area a similiar sort of co-operation did take place between the eventual manufacturers of the 380Z and a group of teachers. Unfortunately, continuing consultation seems difficult to arrange.)

The guidelines for such an operating system should be firstly, simple start up procedures - with correct default selection. Secondly, it must have the ability to control peripherals from within programs. The reason for this is most easily explained using an example. The Schools Council Computers in the Curriculum Project includes a set of programs on economics. One of these programs draws a graph on a screen. Most of the time the student's needs will be satisfied by inspection of the graph on the screen. However, sometimes, perhaps at the conclusion of the session, a student will require a hard copy. It should be a simple matter for it to be produced under system control without the student needing to take further action.

Thirdly, the system must avoid exiting from the program if at all possible. This system will be dealing with completely debugged programs so the only source of error is incorrect user response. The student must be helped to overcome his difficulties so that he provides acceptable responses in future.

Fourthly, where computers/terminals are linked together, e.g. share a common peripheral such as a printer or disc unit, if one user does cause his machine to crash or simply turns it off, it should not affect other users. This may seem obvious but there are manufacturer approved systems existing in educational institutions at the present time where one user switching off his machine can cause the others to loose their programs.

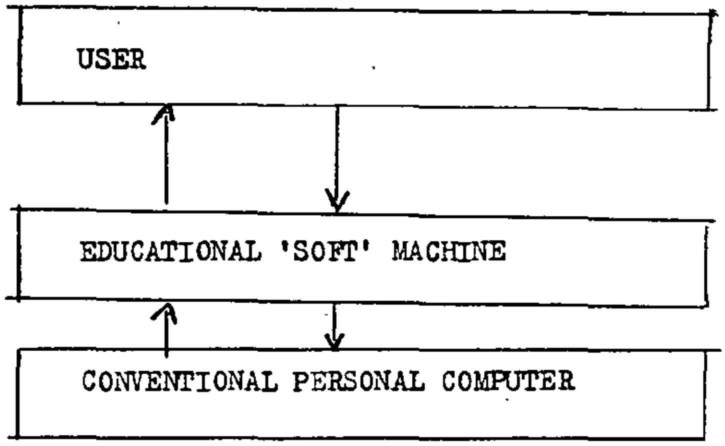
Finally, the operating system must at all times keep the user informed of what is happening.

Some of the points raised above could be considered the province of the interpreter in interactive languages. With the increased use of extra plug in ROMs in systems the area between operating systems and interpreter becomes blurred.

As James (1982) remarks, provision of such systems "requires subtle methods and a great deal of processing power". The foundations for such methods have already been laid and it is possible to develop what James terms "protective ware".

It is unlikely that a machine will be produced complete with an operating system suitable for the perculiar requirements of educational institutions. However, most machines used in education have the facility for expansion. An educational operating system could be devised which was like a "soft" machine. This would interface with the operating system in the machine to provide the protective ware. Such a system in ROM could be supplied with every machine used for education.

The diagram below shows how much a system would operate.



Diag.No. 4.3.

If necessary interfaces for special education peripherals could be included in the 'educational machine' and access to more 'commercial' peripherals left to the personal computer.

This system would have many advantages including increasing portability of CAL packages.

Chapter 5

Hardware.

The dialogue produced by the underlying software and firmware is only part of the man-machine interface, the other part is made up of hardware.

There are three essential requirements for hardware in a CAL environment, namely reliability, flexibility and simplicity of operation. Some aspects of these necessities are the concern of the operating system. Others are intrinsic qualities of the types of hardware chosen.

However carefully a device has been designed to aid the student reach certain educational goals if the device is unreliable or easily damaged the chances of those goals being realised will be lessened.

The Terminal.

A terminal used for CAL has to perform the same basic function required by other users; namely a method of capturing input and a method of outputting information to the student. Two different environments must be considered: use of the system by individuals and use of the system by groups and classes.

Various sorts of terminal have been used for CAL. These vary from the teletypes, which were common to most computer systems until comparatively recently, to the specially designed terminal used by the PLATO system. The latter consisted of touch sensitive high resolution graphics display screens which were transparent so that slides could be back projected on to them.

a) Output.

Output from a CAL system can be categorised as follows:

(i) that required by the user immediately (called immediate use output);

(ii) that required by the user for study at a later time (future use output);

(iii) that required for record keeping and analysis of student performance. (data output).

It is conceivable that a single device could cope with all three functions. If a teletype with a paper tape reader and punch were used then, at the completion of a session, all necessary details could be punched on to paper tape. These could then be fed into the system for analysis at some convenient time.

This system has considerable practical disadvantages. The device is almost entirely mechanical and consequently is less reliable than more electronic devices and also more costly to maintain. Both printer and tape reader and punch are slow.

It is better to look at separate devices to fulfil each of the three functions.

Immediate Use Output.

At the user interface, the first consideration must be given to the output which is for the immediate attention of the user,

If CAL is to be cheap as possible then it is important that education makes use of easily available hardware where it can do so without defeating educational objectives.

Speed of response has been found to be an important trait for user satisfaction with computer systems (Craft (1970), James(1981))

These two criteria indicate that the main output device should be a visual display unit. This also has the advantage of using less paper. It does mean, however, that a second device is required to provide hard copy where necessary. A second disadvantage is that material disappears off the screen. This must be borne in mind by the designer of CAL programs.

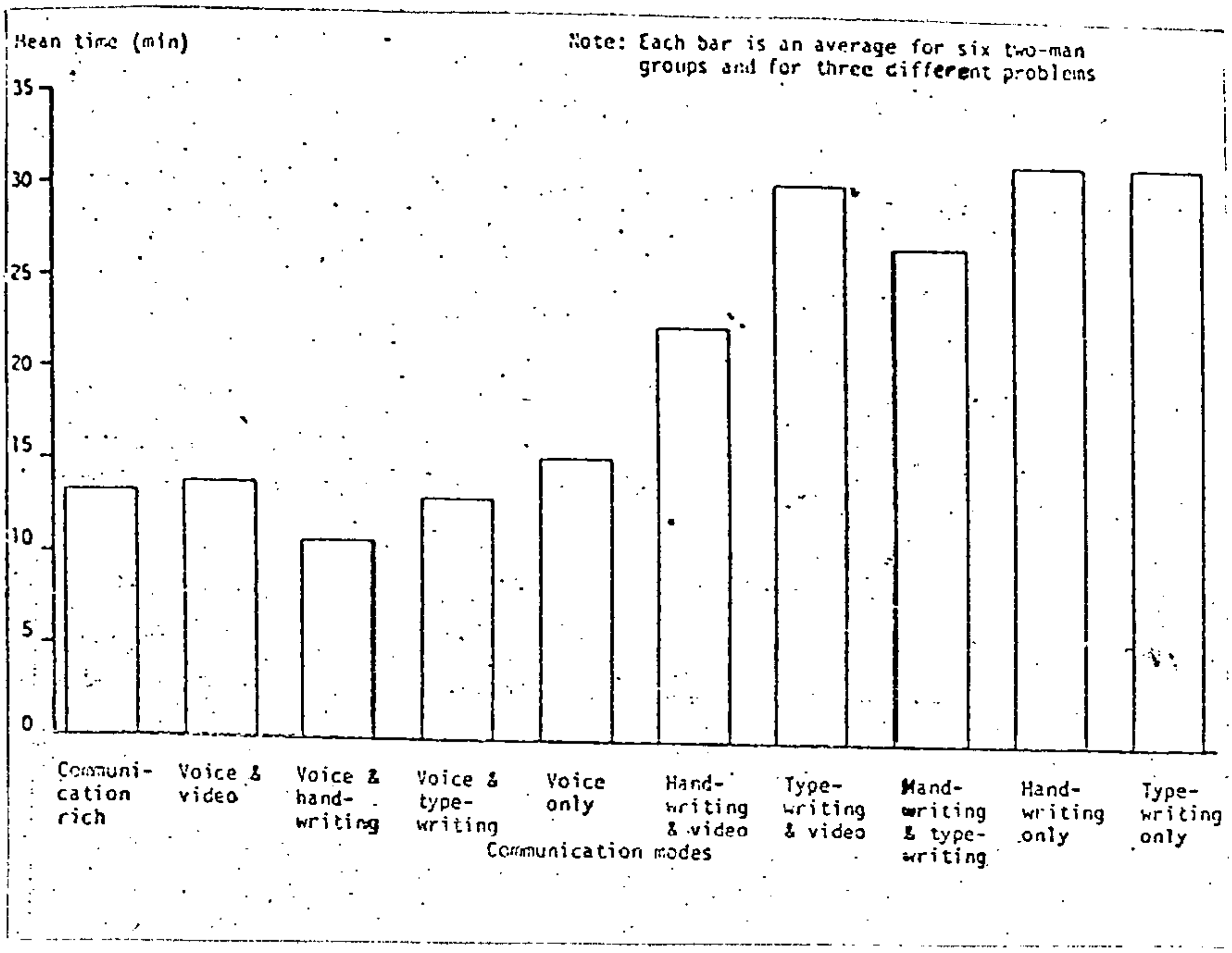
System versus Program.

Information presented to the student by the computer system falls into two categories:

(a) that which is concerned with the program being used by the student;

(b) that concerned with the operation of the system.

Problems are caused by both sets of messages being conveyed by the same medium. In addition, communication is more efficient when more than one channel is used as is indicated by this diagram taken from B Shackel (1979) Dialogues and Language: (Diag. 5.1)



Diag No 5.1

If one is restricted to one device then the two sorts of information could be presented in a different typeface or different parts of the screen, or, with a colour monitor, in different colours. Alternatively, system dialogue could take place in a different "page" which could be swopped with the instructional page. If two devices are available then several possibilities exist.

If the visual channel is still to be used then system messages could be directed to the printer. This implies a printer per terminal which would be expensive. Visual messages could also be sent via a special LCD device. Liquid Crystal Displays can already be obtained which give a 64 X 64 display. This would be sufficient for short system messages.

By adding an audio device, the flexibility of the system would be enhanced and a second communication channel used.

Systems information usually requires a response from only one user. The information presented by the CAL package may need to be used by a whole group. The provision of additional video outlets from the computer gives flexibility in this respect. A large group can view a big screen or indeed small groups discuss the happenings on a number of smaller screens.

Features Of VDU.

Features of VDU. Advantages & Disadvantages.

Advantages & Disadvantages.

It is desirable that a visual display unit and its associated logic used for Computer Aided Learning have certain facilities. The screen must be large enough and the resolution sufficient for a reasonable amount of information to be presented at a time in a large typeface. It is useful when dealing with younger children or less able students to be able to use a large typeface. The great advantage of the computer over the book is the use of animated diagrams so the resolution must be sufficiently high for them to be meaningful. If students have to learn to interpret a diagram because of the poorness of the graphics then this is another barrier to learning and must be avoided.

Character Set.

Upper and lower case, super and subscripting should be possible and available at the same time as other graphics functions. It is important that mathematical and chemical symbols should be properly presented. If a student needs to learn new symbols in order to study a subject using the computer then this increases the learning overhead. The great expansion of knowledge demands an increase in the efficiency of learning. If overheads can be reduced then efficiency will be increased.

The language of mathematics contains a large number of special symbols. These should be able to be displayed on the screen either by using a special ROM which is called by programs employing mathematics or by making it easy for an author to define special characters. The latter approach is preferable because it is more flexible, suggests E.A.Edmonds (1981), and with increasing availability of good cheap graphics facilities, it is relatively easy to achieve. This system of code written for the BBC microcomputers shows just how easily a speaial character can be produced

```
10  VDU  23, 240,28, 28, 8,127, 8, 20, 3465
20  PRINT CHR$ (240)
```

Line 10 creates the special character. Line 20 prints it on a screen.

<u>Resolution.</u>

The resolution of the screen needs to be sufficiently high to accomodate these facilities. On the other hand as one is attempting to present concepts or aid exploration rather than plot precise points, the higher levels of resolution are not required.

If it is educationally desirable for a student to read values from a graph precisely, then he will gain more from plotting it himself than from peering closely at a VDU screen. Curves and shapes presented on the screen must be reasonable representations. Much can be achieved by rescaling where necessary. Within limits the dynamics of a diagram are most important than its precision. Learning theory would suggest that precision can be added to concepts but not concepts to precision.

The currently available resolution on many microcomputers of approximately 300 X 200 points would appear to be adequate. Many such systems permit a small area of text to scroll whilst retaining a frame. This is a useful device. Speed of presentation is important so a system which enables frames of information to be changed quickly is also an aid.

Colour.

The judicious use of colour in diagrams can be educationally valuable but on most small systems the large amount of memory involved could be better utilised by other functions such as increasing the resolution (cf Smith & Blandford 1981).

Computer graphics is of course a rapidly growing art with dramatic implications for the teaching of aesthetics and of design of all sorts. At present most systems are too expensive for the majority of educational institutions.

Finally, concern has been expressed over the effects on health of use of visual display units. Whilst care must be taken that viewing should take place in good physical conditions so that physical strain is reduced, students are unlikely to spend sufficient time using the system for any bad effects to accrue.

Although the question of whether terminals should be provided in study carrels or in open plan situations is outside the scope of this study, such matters need careful consideration. Computer Aided Learning may change patterns of instruction in the future but benefits will only accrue and development continue if it can be accommodated into present educational practice physically as well as philosophically. (Williams,1981; Tagg,1981)

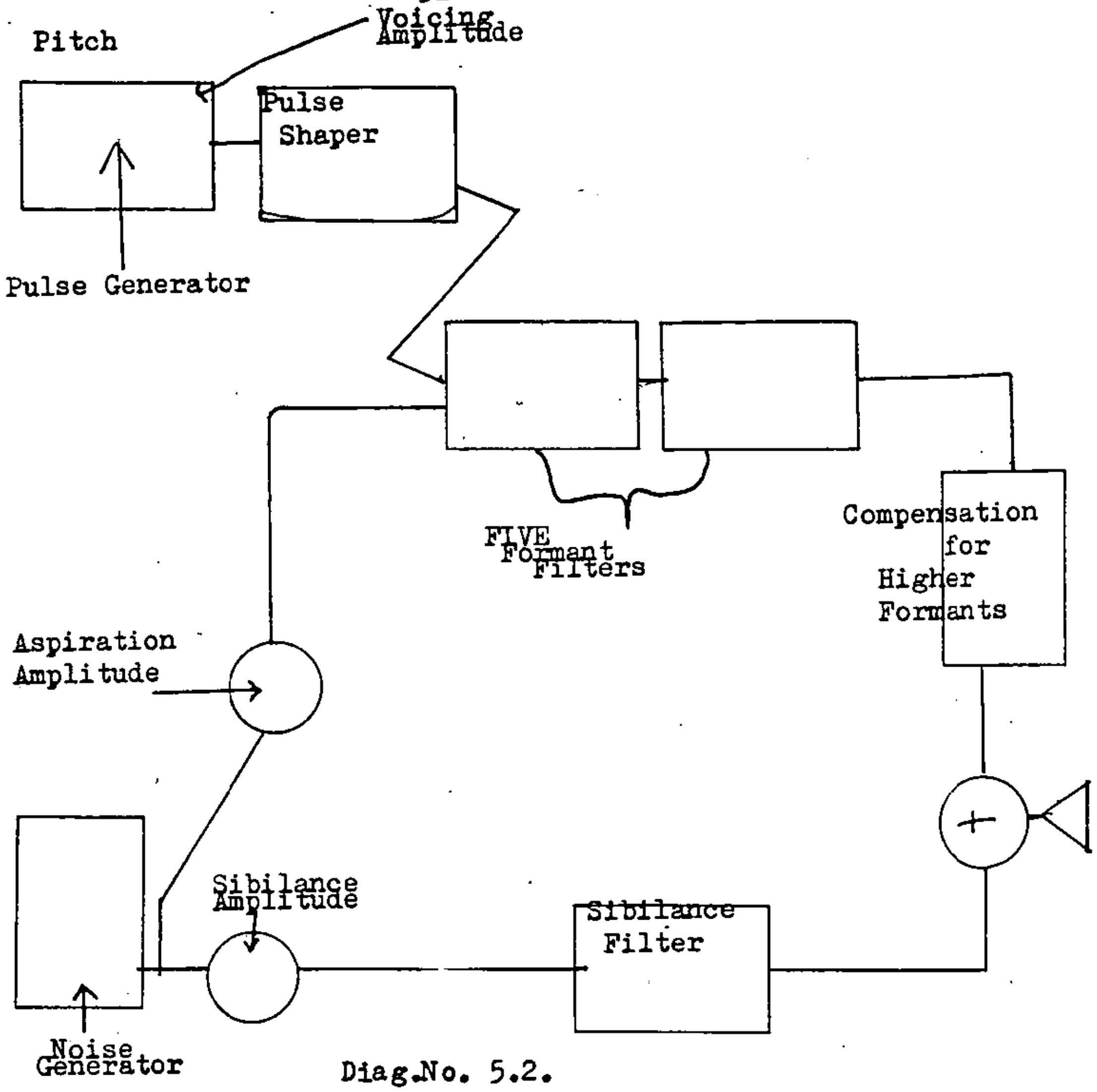
The use of audio channels for output places constraints on the placement of CAL terminals. The state of the art of speech synthesization, however, is such that these devices must be considered seriously.

Sound.

As has already been remarked, (p 34) one method by which system commands and prompts could be separated from the CAL program demands is to use a speech synthesizer. These could also be used as an essential part of a CAL system designed for use by the blind or pertially sighted and by young children or other non-readers. Speech synthesis systems have been around for about 200 years but are still in the early stages of development. A simple speech system using fast sampling A-D converters requires that the speech be sampled at 6 KHz in order to reproduce understandable speech. This means that 6,000 bytes of memory would be needed for every second of speech and also that data would need to be input at a rate of 4,800 bits per second.

Obviously, these requirements pose an impractical strain on the computer system. A considerable amount of effort has been concentrated on the need to reduce them whilst still producing speech of an acceptable quality.

Two methods of solution have been pursued. The first uses decompression techniques and the second uses electronic models of human reproduction systems. A block diagram of a resonant speech synthesizer is shown below.



Diag.No. 5.2.

Vocal tract models are now available on single chips such as the SC-01 and the TI TMS 5100. With the former a 1,000 word vocabulary would require about 6,000 bytes of storage and a data rate of 70 bits per second. The latter needs 64 K bytes to store 600 words and has a data rate 2,400 bits per second. The SC-01 gives unlimited vocabulary but poorer speech quality.

If the speech synthesizer is used for system commands then only a limited vocabulary is necessary. For non-reading CAL operations, a larger vocabulary is important and perhaps good speech quality is less important to someone attending only to that sensory input.

Obviously, the peripheral would have to be designed with one purpose or the other in mind. It would have its own ROM so would not add to the demands made on the system memory.

An alternative approach to this problem is suggested by P.Crabb in Educational Computing, November 1981. He uses a versatile interface and a device developed by Tandberg Ltd for use in language laboratories.

This device is an audio cassette player which can be wound backwards and forwards under software control. He claims that the relevant message can be found in 30 seconds.

Future Use Output.

The second category of output is material which is to be retained by the student for use later. As photographs of the screen do not give sufficient definition a printer must be provided. Many different types of printer are manufactured. As the facility may only be required once or twice per session it seems wasteful to provide one printer per terminal. Where possible a printer should service several machines. Large volumes of output per student are unlikely (and undesirable), so emphasis should be on reliability rather than speed. When considering the VDU, emphasis was placed on a large character set. The printer, therefore, should be of a type which enables this character set and diagrams to be printed.

Where a CAL terminal is being used for remedial instruction then matters for further consideration should be in the student's notes and there will be no need for a printer to be provided.

Printers of this type suggested above are peripherals which need skilled supervision. Consequently it would not be practicable to provide them in situations where a student is using a computer system completely without supervision (i.e. the situation outlined on page 59).

Data Output.

The third category of output relates to record keeping and is connected with the provision of backing store for the system. A solution to this problem is suggested on page 56.

Backing Store.

Simplicity of operation must be the keynote of CAL systems. This criterion must be borne in mind when assessing methods to be used to store programs etc.

Cassettes.

Cassette tape players/recorders are the most common and cheapest method of providing this storage. These players are simple to operate and familiar to many students. They are also slow with read speeds of between 300 and 1200 Band. This means that, either programs must be shert or that the first program will contain instructions to load and run the remaining programs in the suite, without any other action by the student than the responses required by the learning program. Non-trivial programs can be written which will load in about 3 minutes or less.

The disadvantage of the second method is that it is very difficult to restart in the middle of a program. As with this simplest method the user bae hasmindmind is an individual using the system on his own, then perhaps a series of short programs aimed at specific points may be the mast acceptable.

Discs.

The handling of floppy discs requires a greater degree of computer literacy than does the use of cassetts recorders. There are, for instance, a number of ways in which the disc can be inserted into the drive, and also considerable damage can be caused by handling playing surfaces. (This is true also of tape cassettes but more students are likely to be familiar with the media because of the similiarity of audio cassettes).

Discs however provide faster access to more software. With transfer rates of typically 250,000 bits per second, large programs can be read in quickly and also significant amounts of data. Thus for any CAL application which involves significant amounts of data, a disc system is essential but probably requires an environment where some help is available.

One would like to see individual exploration also possible and this might be possible if a number of computers had access via a network to a Winchester disc unit.

There is obviously a limit to the number of programs and data which can be stored on such a device. This would mean in large institutions like DCFE that it would be unable to hold all the programs and data required.

Optical Storage Devices.

In the future large amounts of store are likely to be kept on optical storage devices. The original predictions of the mid-seventies that optical disc memories would be in widespread use in schools by 1980 (cf The Educational Computer 1980 WILSON) have been shown to be optimistic. However, the robustness and high packing density of these discs would seem to make them ideal for use in CAL systems. The total capacity is of the order of 10^{10} bits. The lens is situated 2 mm from the track so dust etc does not have the same effect as with magnetic disc where the head is only 1 millioneth of a metre above the disc.

These discs are a write once only medium so whilst suitable for storing programs and associated data (music, pictures,etc), they are not suitable for recording student progress, learning style, etc. For these purposes some other storage media is necessary.

Bubble memories.

Magnetic bubble memories may well be of use here. These devices are non-volatile and so once a day collection of information could be achieved. Data could then be written to a printer or onto other storage media as necessary via device connections made by computer unit staff. In this way one could collect data which will survive the machine being switched on and off, where the storage media is essentially robust and avoid the consequences of the smaller amount of store available.

The last point is, of course, subject to review as the technology develops. Wilkinson and Horrocks (1980) suggest 10^6 bits as the storage capacity which may be conveniently stored on one board.

At present one assumes that pictures will be stationary but there seems no reason why moving pictures should be incorporated.

Another method of storing large amounts of data until required is to get someone else to do it. In other words, to communicate with someone else's system via a modem and telephone lines.

Input.

Computer output forms one side of the dialogue; user input provides the other part.

Keyboards.

By far the most common method of input to the Computer Aided Learning program is via a keyboard of the conventional QWERTY variety. A keyboard of sufficient quality to withstand educational use is not inexpensive and they have considerable educational disadvantages. The most important of these is the length of time taken by most students to complete the input. The observations undertaken of users of the terminal in the Science Museum, London, showed that users took from one to three seconds to find each key. More thorough researches at Manchester University have produced similiar statistics (HENNESSY, 1981).

Most systems require each line of input to be terminated by pressing the RETURN key. The Science Museum terminal used a SEND key. This was another source of difficulty as users frequently forgot to press this key.

Designs of software which use menu techniques and the equivalent of the BASIC 'GET' instruction can , of course, avoid or minimise these difficulties.

Other Methods.

However, use of conventional keyboards is unsuitable for some learning experiences, It is very "word-orientated" and one tends to wonder at the advantage of the computer over a book. Less literate students have difficulties and the software has to carry large over-heads to deal with the consequences of spelling mistakes.

One solution used by the PLATO system has already been described, (p 44).

"Light pens" have been used to perform similiar functions. These together ith a reasonable graphics program, may be used for very open ended work in aesthetics and industrial design. Such facilities also enable special characters to be used such as 'x' for multiplication. If care has been taken to provide output which uses these characters, it makes little sense not to provide the same facility for input.

Keypads.

Other methods have been used, One such, employs touch sensitive keypads which can be overlaid by pieces pf paper containing the keywords etc, required by the particular lesson. Birmingham Computer Centre is doing considerable work on this. A similar method has barcodes at appropriate places on the worksheets which can be read with an inexpensive barcode reader.

Educational institutions spend a considerable amount of time teaching people to write and punctuation marks make good terminations. It has been possible for some time to transmit handwriting electronically. Recently a microcomputer, called a "Penputer" has come onto the market. This accepts input handwritten onto a tablet similar to the type used for computer graphics. Ocksman and Chaponis' work indicated that communication using voice and handwriting led to more efficient problem solving than other combinations as diagram number 5.1. on page 47 shows.

Further work on "Penputer" lines may well provide a viable communication system for CAL. (Wittem, 1980).

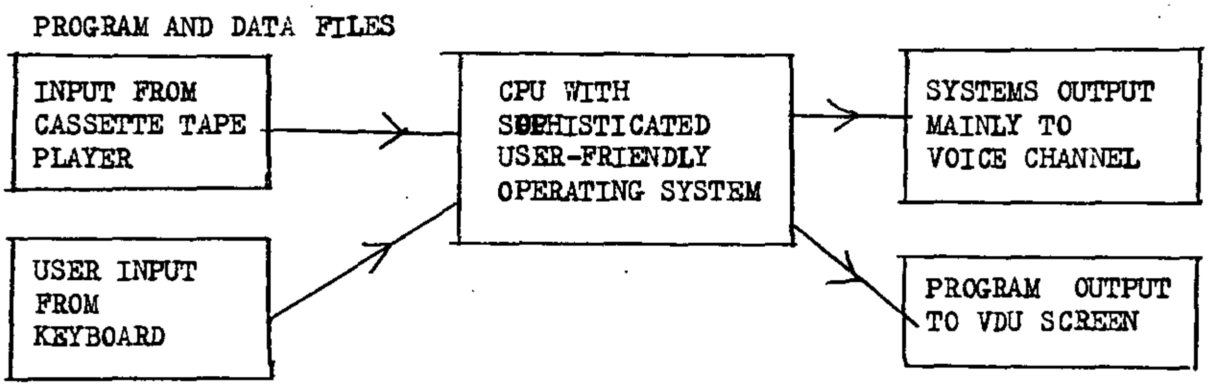
To be able to communicate orally with the computer in natural language would be very splendid but, despite a great amount of work in this field, it is not at present a practicable proposition. Oral methods are not in all cases the most suitable method of instruction.

With regard to system commands where the dialogue is of a restricted nature, recent researches have suggested that speech recognition could be used. Here one is very much dealing with the present frontier of knowledge and one would think that a "handwritten" system would be likely to be more reliable for some time to come.

Evidently a variety of methods of input must be possible for any CAL systems Most microcomputers already have the hardware facilities to permit this. The suggested "protective ware" would provide the software requirements. No consideration has been given to the memory size required by this system because development is taking place at such a rate that it is impossible to be definitive. Some guidelines can be identified. The protective software will reside in ROM on an extension board. The host machine will require at least 48 K of RAM to handle the HRG output.

Machines which are to be used for remedial teaching and drill perhaps need less memory but a good operating system is even more essential, as in general, skilled help will not be available.

In this environment it is even more essential that equipment should be reliable and easy to operate. Consequently the computer system should be very simple like the system sketched below:



Diag. No. 5.3.

Many of the aspects of computer operation which confuse the inexperienced user arise from the desire of computer system designers to produce an adaptable machine. The system above is intended like 'games playing' machines merely to load and run programs. Space thus saved in the operating system can then be devoted to user friendliness without increasing the amount of storage involved.

This of cpurse is a specialised machine.

Flexibility is required in the basic CAL system so that technological advances can be incorporated as they become available. Technological advance has caused hardware and software to become intertwined. The hardware environment has influences on the CAL programs implemented upon it. Similarly, the software environment has its effect.

Chapter 6

Software.

There are two aspects of software which need consideration. For both programs and the languages in which they are written have implications for the design of the computer system.

Languages.

If the programs available to teachers are suitable to their purposes then the programming language used is of little concern to the teacher. However a teacher may wish to alter programs slightly to fit individual circumstances and more importantly the language in which it is written has effects on the program.

BASIC.

Many programs are written in BASIC. There are many reasons for this. It is the main language used for actual programming instruction in schools. BASIC interpreters are available for all of the popular microprocessors used and even reside in ROM with some of them. It is an interactive language. It is not difficult to write drill type CAL programs in BASIC and many teachers could and do write their own after a few hours instruction.

What then are the difficulties?

The lack of structure inherent in the language causes problems for the programmer as soon as the logic of the program exceeds a fairly low level of complexity.

A timed "get" as incorporated in some more advanced BASIC interpreters enables help routines to be entered if students are completely stuck for a response. 'Get' on error, etc, also allows good exit routines to be incorporated into programs.

good exit routines to be incorporated into programs.

A major problem is that the string input must exactly match the data held in the program.

PILOT.

PILOT attempts to overcome this difficulty by providing a facility within BASIC for a number of responses to be recognised as right or wrong. This useful facility is linked to a conditional jump so that branching programs can be easily written.

However, as PILOT is embedded in BASIC, the fundamental problems caused by the language's lack of structure remains. These have been overcome to some extent by development of structured BASICs such as COMAL (CHRISTENSEN et al 1981).

Other Languages.

Other programming languages with better structures are of course used for producing CAL programs. In the main, programs in these languages are written by professional programmers. For a teacher to become sufficiently adept to produce worthwhile programs requires a considerable investment in time which might be better spent elsewhere. This is particularly true of such otherwise suitable languages as LISP. LISP might well provide an ideal environment for CAL programs but it is very much a programmers' language which is practically never learnt as a first language.

In most general purpose languages the problem of the interpretation of responses remains. This difficulty can be overcome to some extent by use of menu selection procedures or by employing software controlled keying systems as suggested in the hardware section. This approach produces a dilemma when the system is used for problem solving, Here presentation of alternatives does not allow sufficient student responses and defeats the end goal. Where answers are numerical, ordinary error checking of course answers the case.

Author Languages.

Another approach is to use the so called "author" languages of which TUTOR is an example. This is the language used for the PLATO system. Some 10,000 courses have been written in TUTOR for this system. However, no TUTOR compiler exists which could be implemented on other machines, so these courses are not portable.

Computer conferencing is a method of holding discussions between people at different sites. Each person has access to the input of each other person and also to a computer databases. Some of the software problems involved use similar to those encountered in designing computer aided learning software.

It was not found possible to use TUTOR for computer conferencing purposes (Hiltz and Turoff 1978) so it would seem that TUTOR is so well adapted to its system that it could not be used even for slightly different purposes on the same hardware.

To adapt PLATO (and TUTOR) for use on microprocessors presents considerable problems not least of store size. (Although to permit servicing of 1000 terminals, the actual amount of store available per user on PLATO is small.) The authors of the PLATO system are, however, working on a micro PLATO system.

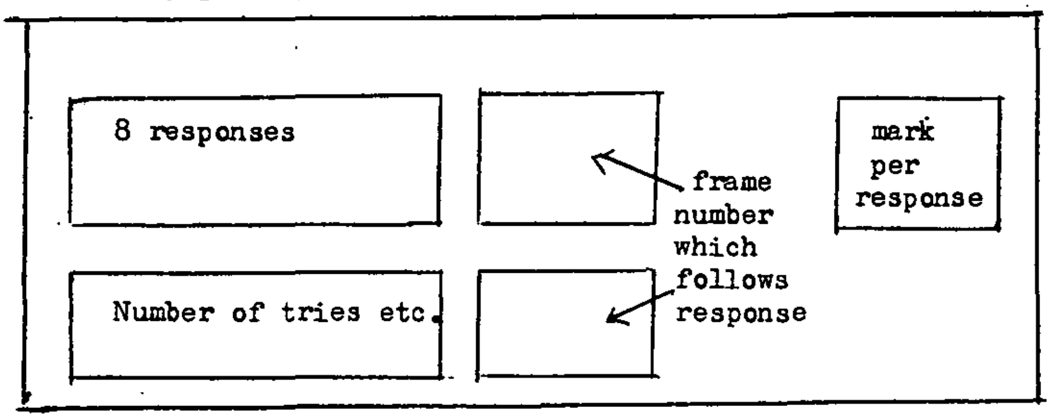
Although 88% of teachers in a recent evaluation (Hawkins 1979) study would use the PLATO system again, 57% did not use TUTOR at all and only 10% found TUTOR simple to use.

A very interesting development has occurred with the production of PETCAI (due to be released January 1982). PETCAI is an author language designed on the Commodore PET computer. The principles, however, could be adapted to other computers. A form filling approach is adopted ans the CAL program is built up in a hierarchical manner. A course consists of a number of lessons and a lesson consists of a number of frames. Each frame consists of two items:

(a) a text page which contains the material presented to the student;

(b) a control which contains the instructions for the program.

A control page is in this format:



Diag.No. 6.1.

The subject and frame fields are the same as for the text pages. The remaining fields are for responses (upto 23 characters) - the frame number to which the program should go on a particular response - upto eight can be accomodated and the score connected with the response where necessary. Under this panel come fields which allow for a restriction on the number of tries and on the time and one which deals with a bad response or a 'return' only repsonse. This last of course is a solution to the particular operating system problem mentioned earlier.

Response matching initially checks the string as usual. If a match is found then the response is converted into a phonetic representation and this is checked against the sought for response. Only after this has failed does it become a "bad response".

The algorithm used for generating the phonetic representation does not deal with all eventualities (silent consonants give problems for instance) but one is assumed that it works for approximately 90 % of responses.

Sample text and control frames from a program designed for individual revision of trignometrical identities are shown in Appendix 1.

The writing of the program of learning requires as much care and planning as any other programmed learning course. The inter-relation of paths through the program, the reasons for 'bad' responses, and the 'bad' responses themselves should be thought out before attempting to use the package.

The package is not difficult to use. Better editing facilities would make it easier but the package would then require more than 32K of RAM. Much thought and planning is required before using the package ;however, with its present editing facilities.

At present the system will only produce Computer Aided Learning programs, which are very textual in content. Diagrams and graphs are possible but no movement is possible within the frame.

However, discussions have taken place with the author concerning the possibility of incorporating a library of subroutines within the system. These might possibly be stored on a ROM in the computer that the system is run on. When a teacher wished to use a particular facility, he would call it up, provide the necessary parameters and thus incorporate it within his program. The PETCAL system would then provide a 'toolkit' of subroutines for the construction of CAL programs.

LOGO displays yet another approach in which the language itself becomes the medium of learning. Developed at the Massachussets Institute of Technology in the early 1970s by Seymour Papert(1971), this language is a very high level language whose instruction set is limited but extremely powerful. These instructions are used by student or teacher to build his own procedures which then become part of the language. Research work using LOGO within educational institutions is undertaken at Edinburgh University where Ross (1981) describes LOGO as the computer equivalent of MECANNO. The designs of the language or of the construction set decide on the kit of parts but the user may construct a great variety of structure with those parts.

LOGO has been used to develop mathematical concepts in primary school children and for remedial work with student teachers.

The research is still in progress but preliminary results indicate that LOGO is likely to make a significant contribution to the teaching of mathematics.

LOGO can be implemented in microcomputers of the sort currently used in education. For older age groups capable of formal operations, input is via a normal keyboard and output is on to a visual display screen. A resolution in the region of 300 x 200 is required. Younger children use a special keypad and a device which draws patterns on paper on the floor.

As well as languages in which CAL programs are embedded, software tools are required to analyse student behaviour. One such was incorporated into the TICCITT system. This analysed a student performance over a unit of work and prescribed the next unit. Evaluaters of the system report that it worked successfully (Hartley, 1981).

Programs.

However carefully the hardware and software environment of a CAL system have been designed, little is of educational value unless good material is written on it. On the other hand, without a good environment, writing good material is difficult and tedious.

Many of the details of actual program construction in CAL have already been dealt with in the sections dealing with operating systems, programming languages and educational theory. In addition the principles of good dialogue construction are as important within a program as without it. However, certain general principles can be stated. These are, I think, put most succintly by R Lewis (1981).

(i) The CAL unit has to be integrated to other teaching resources and integrated with them where appropriate.

(ii) The CAL "courseware" must communicate adequately the aims of the authors to, as yet inexperienced, teacher users.

(iii) Even though a teacher may not wish to use prepared student material, at least it can convey clearly the aims and experience of the authors.

(iv) Within the CAL unit, printed material is important because it provides essential guidance.

(v) Material in the Socratic form provides a framework both for the author creating a unit and also for the student being led through the topic. Each question or problem forms part of a sequence which can become more open ended as the topic becomes more. This also offers more able students greater challenges.

Hartley (1981) suggested that "adaptive" CAL programs should be written within the following framework. A program should have:

(a) knowledge of the subject to be taught;

(b) knowledge of the student and his performance;

(c) knowledge of suitable teaching skills;

(d) a theory of how to apply such skills in particular cases.

Both sets of principles can be criticised on the grounds of being too vague and general. The second set in particular would seem to describe the criteria for a teacher preparing a course not just a program that is part of the course.

Lewis goes on however to consider just one section of the design decisions to be made by authors of CAL programs, namely the display. He identifies no less than eight factors which must be considered by the designer. Further, he suggests that the program must be flexible so that student (or teacher in the case of classroom use) should have control over these factors. In addition, he suggests that the dialogue should be able to be altered by teachers when desirable. This would enable the teacher to incorporate local background knowledge.

In conclusion, Lewis calls for flexibility in design so that programs can be adapted to new technologies.

After many years, the Computers in the Curriculum programs remain amongst the best available.

Of the four types of Computer Aided Learning which can be distinguished; drill, programmed instruction, simulation and problem solving and the use of data bases, most of the programs written by teachers fall into the drill category.

They tend to be linear, to lack proper exit routines and, without the motivating qualities of the computer terminal, would be as interesting to the pupil as nineteenth century spelling books.

Many of their defects are due to the environment for which they are written. With improved systems available, it is likely that programs also will improve.

A list of programs available at Derby College of Further Education is given in Appendix 2. Out of more than 400 examined these were the only ones felt to be worth putting on file. Many of these have some defects.

Commercially available programs are more likely to be branching and to use simulations as a teaching method. Most of these programs are aimed at upper ability bands and higher age levels. One exception to this is the Computers in the Curriculum Home Heating package. This program contains many parameters which need to be input by the student. Each parameter has a default value and the status of the house design could be requested at any time. This means that a student can always find out where he is. This is very important in all problem solving and data base use types of Computer Aided Learning. It is all too easy for a student to get lost; particularly when using a visual display unit.

Research projects such as SCHOLAR and the tutoring programs of Kinball and O'Shea attempted more general teaching strategies. These have been used more for research into learning theories than for practical teaching applications.

The "WEST" (Barton,1979) coaching project seeks to generate explanations and hints for the student. In order to do this it needs a knowledge of learning strategies.

Software Availability.

With the setting up of the Regional Computer Centres under the Micro-electronics in Education Project an explosion of software is expected. Fiveways is amongst the earliest to be produced under this scheme. A description of this software is in Appendix 2. The ability to transform a microcomputer into a smart terminal for a nationally available network means greater access to such software.

If all educational systems contained the protective software described earlier, then such software could be used by all. Various ingenious schemes of recompensing the authors have been suggested (Burke,1982).

For instance Commodore Machines Ltd, (1982), have proposed establishing a data base called PETNET which could be accessed by users of PET machines fitted with the necessary interface. As well as acting as a more conventional data base PETNET would also offer software. An author could place his piece of software on the system. A user requiring this piece of software would be informed of its price. If the user downloads the program then its price is added to the users' bill for use of the system. The money when collected is distributed to the author.

Prestel is also considering such a scheme.

Other methods require purchasers to fit PROMs to their machines or reformat some sectors on discs so that the disc cannot be copied.

The whole problem of 'public domain software' remains to be solved. In Scotland an attempt is being made to set up a library of Computer Assisted Learning software but difficulties are being encountered (see Walker,1982).

Data Bases.

Design Factors.

The use of computerised databases by students is a new field which is being actively developed by the Council for Educational Technology. Projects have been set up at Hatfield and Brighton to investigate telesoftware using both the Prestel and Ceefax and Oracle systems. Use of software via these systems may well be educationally useful. However use of data bases by students may be of little educational value unless the experience is carefully structured as suggested by Hartley (1981). The difficulties inherent in designing even a titles index for a narrow field were recognised long ago by such designers as Bottle (1971).

As more sophisticated data bases become available for educational use it will be desirable to incorporate Nievergelt and Weydert's idea of a 'trail' (1980). A 'trial' enables a user to have complete information about the state of the dialogue, to investigate the history of the dialogue, to mark and revisit specific points and to reuse trails followed during previous sessions. Student users of data base systems will need more support than other users because of the formers age and inexperience. This support may well become available as designers move "from the stage of individual commands to the long-overdue stage of systematic design" (Nievergelt and Weydert p 337).

Microquery.

The Micro Query package developed by the Advisory Unit for Computer Based Education is one interesting aspect of the use of computers as a data base. This package has been developed from a similar package which runs on a minicomputer.

The package is in two parts. The first part enables users to interrogate existing data bases and the second gives facilities for the setting up of new data bases. (Extracts from the accompanying booklets are in Appendix 4)

Both packages include a 'Help' facility to aid in running the package and in addition package 1 includes an 'Explain' facility which aids interrogation of the data base. The information for this is contained in a file created by the author as he sets up a particular data base.

The package once set up is very easy to use. Data bases already a available include census records for various villages in the last century, astronomical data, nutritional data and career information.

The booklets include suggestions for use of the data bases in the classroom. For example the suggestions beneath relate to a data base which holds census data.

> Investigate the suggestion that sons followed their father's trades.
>
> It has been suggested that married couples in their twenties were forced, by circumstance to live in one or other of the family homes. Investigate this suggestion.

New data bases are being added continually. Information on these can be obtained from the nationally available data base PRESTEL.

Computer Assisted Learning in Mathematics.

Most of the above points apply to all computer assisted learning regardless of the discipline within which it is being used. By concentrating one discipline it is possible to specify needs more precisely and alos to look at important new development.

The two areas which have attracted most attention in computer assisted learning in mathematica are at opposite ends of the range , namely drill and exploration.

Drill Programs.

Programs designed to give practice in a particular skill must appear to be amongst the easiest computer assisted learning programs to write. However, if the work using the computer system is to be congruent with lessons learnt by other means a number of pitfalls need to be avoided much as the examples below.

Generation of Operands.

This is often done by using a built in random number generator. Care should be taken that the questions so produced are neither trivial or too often repeated. For example, an occassional addition of 1 or 0 may be useful but a large number serve little purpose.

Screen layout.

Where answers have to be inserted care should be taken that the order of insertion is the natural order resulting from the algorithm being tested. If, for example, the question is this:

$$\begin{array}{r} 729 \\ +\ 431 \\ \hline \\ \hline \end{array}$$

then the first insertion by the student should be the '0' in the least significant not '1' in the most significant.

In order to make best use of the system of feedback which gives the use of a computer system an advantage over a set of written exercises partial results should be tested for correctness.

Partial results and 'carries' may need to be displayed. In this way, even the merest pedestrian of drill type programs can help the student to work with understanding. A 'form filling' approach to more complex calculations can guide a student in the correct layout of work.

This approach can be particularly important in packages designed for individual use. In further education, in particular there is frequently a need to provide students with extra work to remedy weaknesses or to cover work which has been missed. Whilst it is unlikely that programs will have been written to furnish every individual need, it is possible to cover the main topics for each of the Technician Education Council units in Mathematics. To these it would be useful to add some revision courses on such topics as algebraic manipulation.

In all such "self-help" programs, control should remain with the student so that sections can be skipped or ended early to suit individual needs. Worksheets should be provided to accompany the programs. The computer programs, worksheets and computer system should be available in a central resource area such as the library.

For younger children, imaginative use of graphics can provide very acceptable rewards for correct responses. Timing of responses introduces an element of competing against yourself. A degree of stress, as Hebb (1955) showed, leads to increased efficiency in learning.

The competitive element is also present in many games and these can, of course, provide a vehicle for practice in mathematics. The new technology provides a medium for adaptation of old games and will also lead to the production of new ones. The dearth of new games at the moment is probably a tribute to the newness of the technology.

Exploration.

Games, simulations and problem solving are linked ideas which may well provide a new direction to the teaching of mathematics. As H.D.Peckham (1976) wrote "What is needed is a rethinking of the fundamental objectives of every course. The computer gives us the capability to short circuit the linear set of prerequises dictating that course. If we are brutually honest with ourselves there is an incredible investment of mathematics required to gain very modest returns in engineering and physics classrooms"(p.40) This "incredible investment" has held back attempts to design "applicable mathematics syllabuses" such as those developed at Reading University and by Schools Council's "Mathematics for the Majority" Project.

However, a CAL package such as the Home Heating package already referred to, can elimate the overhead and hence aid mathematical development by providing a secure link between mathematics and the student's construction of reality.

The more "open ended" the problem set to the student, the greater the demands made on the system. The difficulties encountered in programming mathematical problems at this level become identical with those already discussed for the system as a whole.

Exploration of structures such as those of Euclidean geometry and finite groups (with small numbers of elements) can be greatly facilitated by use of a computer. The system can handle the clerical work leaving the student free to think. In addition, the program can suggest hypotheses for exploration.

Programs such as SOPHIE which attempt a Socratic approach rapidly become very long. An approach using a language such as LOGO with its powerful primitives seems likely to yield more useful results as the research at Edinburgh University has indicated.

Seymour Papert (1971) claims that LOGO allows children to romp creatively within mathematics. He suggests that new branches of mathematics may need to be developed for the purpose of teaching mathematics. The implication is that these will involve the use of computer systems.

"Thing lab's" (1979) developed by Xerox at the Palo Alto Research Centre, is a similar type of approach. At present it requires a very large computer but the team are working on a system which would run on a micro computer. The use of a micro computer as an intelligent terminal would also give a student access to a suitable system. The design philsophy behind "Thing lab" is similar to the early 'memex' concept of Bush (1945).

Both Logo and Thing labs are elaborate programs. Considerable personal satisfaction can result from use of simple programs such as the one below.

```
10 DIM A(16)
20 MOME2:GCOL0,3:MOVE0,512:DRAW1280,512:MOVE640,0
25DRAW640,1024:VDU29,128,0,2
30 PRINT
40 VDU28,0,4,9,0
50 AL=PI/160:B=1
60 INPUT"ORDER"J,VALUE"G
65 IF  J 0 THEN 20
70 A(J)=G
80 PH=PI*2
90 FOR Q=-640 TO640 STEP 2
100 PH=PH+AL
110 Y=30*(A(0)+A(1)*PH+A(2)*PH 2+A(3)*PH 3+A(4)*PH 4+A(5)*PH 5
           +A(6)*PH 6+A(7)*PH 7
120 K=B MOD7+1:GCOL 0,K:PLOT69,Q,Y
130 NEXT Q
140 B=B+1
150 IF B 15 THEN 60
160 END
```

This program shows the effect on the graph of a function of altering the coefficients. Each graph appears in a different colour. Eight different colours are available and the resolution is sufficient for the curves to appear smooth.

The success of this program depends on the facilities available from the computer system and the correct educational environment.

Chapter 7

Conclusion.

Factors which must be taken into account in the design of the software, the hardware and the operating system of a computer assisted learning system have been considered. One element within the system has not been completely investigated and that is the human element.

The student has been considered as an element in the system. The teacher and the institution within which the system operates need also to be considered for a full system design (see Rouse,1980; Hennessey, 1982). However, the effects of computer assisted learning on educational institutions will be many in number and variable in importance. These effects will also be inextricably linked with, and possibly subordinate to, the effects of technology on society as a whole.

If the computer system design is flexible and robust, then it will be able to be adapted to any institutional changes which may take place during its working life. One human element in the system which is necessary at present, is the provision of technical support to a teacher. Foe example, some software packages require parameters to be altered before they can be run on a particular system.

This support would be less necessary if computer systems in educational use incorporated a "soft machine" feature which was referred to in chapter 4.

The concept of a soft machine which interfaces educational users with existing micro-computers and peripherals is technically feasible. Its arrival is already foreshadowed in the operating facilities available on the latest machines.

The existence of this facility, a core for the ergonomics of the user interface and a due regard for progress in educational theory will ensure that computer assisted learning will fulfill its promise. Attention to these considerations is therefore necessary in the design of computer systems for computer aided learning. For as Sherwood et al wrote

"The system design has important bearing on the styles of possible pedagogy. This point has been systematically ignored by too many researchers who have thought that questions to pedagogical questions, not realising that the limitations of their systems were distorting their research results". (1973, p 37).

APPENDIX 1

The PETCAI package showing the text and control frames

Both styles of output are produced by the package

The text frame:

This is what the student sees

```
Subject:trig1 _                    000   Frame:100

You are allowed 2 goes at each question

You will be given:
                  5 marks for each answer corre
ct at the first attempt;
                  2 marks for each answer corre
ct at the second attempt;
 After 2 goes you will be given a hint.
A correct answer after a hint scores 1 m
ark.

PLEASE WRITE" A SQUARED" AS "A^2"


  QUESTION 1


sin A / cos A =?
```

Subject trial _   000   Frame: 100

Anticipated response	Frame	Score
TAN A	101	5
TANA	101	5
TAN A	101	5
COT A	102	0
—	000	0
—	000	0
—	000	0
—	000	0

If the number of retries exceeds 000

then the next frame shown will be 103

Bad response or "RETURN" goes to 103

Response time in secs. is set to 030

If time is up, then go to frame 103

For this frame PHONETIC mode is ON

Subject:trig1 _ 000 Frame:100

Anticipated response	Frame	Score
TAN A	101	5
TANA	101	5
TAN A	101	5
COT A	102	0
-	000	0
-	000	0
-	000	0
-	000	0

If the number of retries exceeds 000

then the next frame shown will be 103

Bad response or "RETURN" goes to 103

Response time in secs is set to 030

If time is up, then go to frame 103

For this frame PHONETIC mode is ON

Subject:trig1 _ 000 Frame:100

You are allowed 2 goes at each question

You will be given:

5 marks for each answer corre ct at the first attempt;

2 marks for each answer corre ct at the second attempt;

After 2 goes you will be given a hint. A correct answer after a hint scores 1 m ark.

PLEASE WRITE" A SQUARED" AS "A**2"

QUESTION 1

sin A / cos A =?

APPENDIX 2

List of CAL Programs

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
MGP	Menu graph plotter	3802	Disc
FACTL	Factorials	"	"
REVERSE	Maths game	"	"
AUTOFRAC	Fractions - not interactive but answers written in normal form e.g. $\frac{3}{7}$	"	"
WASPS	Probability	"	"
BINORMAL	Draws graph of binormal distribution	"	"
TABLES	Multiplication Practice	"	"
ADDTEST	Timed addition test	"	"
PRIME	Investigates if a number is prime	"	"
MULTEST	Timed multiplication test	"	"
LINO	Addition and Subtraction of signed integers	"	"
CORR	Peasons and Spearmans Correlations for use by Maths/Science/Geography students	"	"
HURKLE	Maths game using coordinates	"	"
FTRAINS	Remedial Mathematics nice output	"	"
VECTORS	Vectors and coordinates	"	"
SNAP	Remedial Mathematics Fractions Game	"	"

MATHEMATICS (2)

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
COIN	Tosses coin, analyses results also sequences of tosses	3802	Disc
DICE	Graphs of results of 4, 6 and 12 sided dice	"	"
TRAINSV 5	Remedial mathematics	"	"
MATRIX	Demonstration of Matrix Multiplication	"	"
PI	Evaluation of PI by Monte Carlo method	"	"
JANEPLUS	Remedial Maths	"	"
BASES	Practice in bases 2 and 5	"	"
RANDOM	Selection of games illustrating use of RANDOM function	"	"
TALLY) TIMES)	Remedial Maths	"	"
FIND	Find a number between 1 and 100	"	"

BIOLOGY (1)

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
TRANS	Transpiration	RML 3802	Disc
HERED 1	Inheritance in Drosophil	"	"
HERED 2	" " Mice	"	"
HERED 3	" " Human	"	"
HERED 4	" "	"	"
HERED 5	" "	"	"
PREY		"	"
POND 1		"	"
POND 2		"	"
COUNTR	Counter Current System Calculations	"	"
ENERGY	Human energy expenditure	"	"
STATS	Statistics for biologists means standard deviation x^2 etc.	"	"

All the above programs are produced by Chelsea College for the Schools Council Computers in the Curriculum Scheme. The programs are also available on cassettes for use on PETS. Teacher's and student's notes are required and these are available from

All these programs were originally written for machines without visual display units. Consequently, although they produce graphs and tables, they do not exploit the facilities offered by the sort of computers we have in college. The programs are being rewritten so that they do exploit these facilities. Publication date has not yet been announced.

BIOLOGY (2)

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
MENU	Analysis of meal contents protein, calories, etc. See "Computer Software for Schools" in MB5.	3802	Disc

GEOGRAPHY

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
GRAVITY) WEBER)	HUFF'S gravity model Geographical Association programs. Hand book needed.	3802	Disc
GRIDREFS	Useful but boring	"	"
POPULATE	Improved version of program in Computer Software for Schools.	"	"
TRANSPOT	Settlement and transport patterns in Cornwall	"	"
DIQAT	Drought simulation	"	"
CATTLE	Beef cattle in Australia	"	"
U.K. MAP		"	"

GENERAL PURPOSE, GAMES AND ADMINISTRATION

TITLE	PURPOSE/COMMENT	MACHINE/MEDIA	
SLALOM	Game	3802	Disc
LANDER	Land on any planet No instructions	"	"
OTHELLO	Good	"	"
PONTOON		"	"
BRANDS		"	"
DRAKE	Historical Simulation of F. Drake's circumnavigation	"	"
CAREERS) GRADJOB)	Interesting demonstrations of use of data base	"	"
ISLAND	Simulation of spread of fire on island - could be used for geography or mathematics.	"	"
DICKIE	Estimating Distances	"	"
AIRWAYS	Simulation of Airways booking system	"	"
RECORDS	School Records System	"	"
HANGMAN 2	Usual game	"	"
HANOI	Demonstration of of Hanoi	"	"

GENERAL PURPOSE, GAMES AND ADMINISTRATION

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
LABYR	Fantasy Game	3802	Disc
ADVERT	Amusing	"	"
DUGRACE	Game	"	"
ROMAN	Demonstration of graphics	"	"
AIRCRAFT	Game	"	"
LANDER 2	A good moon lander	"	"
TT1) TT2) TT3) TT4) TT5) TT6) NOTETT 7)	Set of programs for producing timetables	"	"
NIM	Game	"	"

CHEMISTRY

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA	
CHEM		3802	Disc
CHEM EQUF		"	"

ECONOMICS

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA
COBWEB) AGCOM 1) AGCOM 2) CREDIT) MONPOL) INTRAD) MAXPRO) MULTSC)	Schools Council Programs from Chelsea. Documentation from Longmans D. Cutting has a copy	Available on 3802 disc and PET cassette

LANGUAGES

TITLE	SUBJECT AREA/COMMENT	MACHINE/MEDIA
SPELL		3802 High Resolution Graphics Disc
FRHM 1 FRHM 2	Hangman in French 2 levels	3802 Disc
FVERB	French verbs - well constructed programs	3802 Disc

APPENDIX 3

Software from FIVEWAYS

A FURTHER NINE PACKAGES FROM FIVE WAYS

Each package will consist of a disk, teachers' notes, and full instructions for use. The disks are available in versions for Apple II and RML 380Z; versions for the BBC machine are also in preparation.

The programs and accompanying material have been written so that those with little or no knowledge of computers can use them with confidence and ease.

ACCOUNTS I and ACCOUNTS II* *age 14+* £12.50 each

Two separate packages which give practice in introductory accounts, including double entry book-keeping to trial balance and trading profit and loss, to illustrate keeping the accounts of a small business.

HYDROGEN SPECTRUM *age 16+* £20.00

Program 1 is a dynamic model for use as a visual aid when teaching the interpretation of the line emission spectrum of atomic hydrogen. Using the same model, Program 2 and the associated Student Booklet guide the pupil through a series of graded exercises on hydrogen spectra.

SYMBOLS TO MOLES* *age 13-16* £12.50

Practice in the use of chemical symbols, valencies, formulae, equation writing, and mole concept calculations.

REPONDEZ I* *age 11-16* £12.50

Practice in French verb formation (present tense) in translation from English.

COMPRENEZ I* *age 11-16* £12.50

Multiple choice comprehension exercises, French to English (present tense), to provide structured practice in grammar and vocabulary.

YOUNG'S SLITS *age 15+* £15.00

A simulation of the Young's Slits experiment to investigate the wave formed from the interference of two coherent waves with various path differences.

LENSES* *age 14+* £12.50

This illustrates the formation of images by lenses and mirrors using high-resolution dynamic ray diagrams.

WEATHER *age 13+* £20.00

This program gives a bank of data in the form of synoptic charts which can be used to teach elementary meteorology.

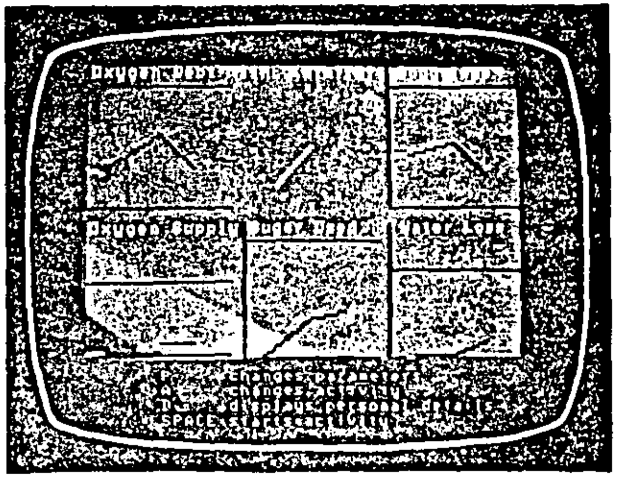
Physiological Simulation

13-18 years; Biology

In this simulation of an active human, the user, representing the brain, has to keep the body (provided by the computer) alive while performing a series of physical activities. Once the sex, age, obesity, vital capacity, and blood volume of the person have been determined, the brain can vary the rate of breathing, the breath volume, and the sweating rate, while the human performs up to three different activities (chosen from a list of ten activities — from sleeping to cross-country running).

The ability to examine the effect of altering a single variable in a complex system is a basic requirement of investigative science. The program simulates the effect of user-controlled variables in an exciting and dynamic way. It also allows the user extensive comparison with and examination of national data on certain human statistics.

* The simulation reinforces the idea of a feedback between the physiological concepts (oxygen debt, respiration, and temperature)
* Pupils can input their own personal details and hence make much more extensive use of data normally acquired during the standard human physiological practicals
* The program provokes lively discussion, which the teacher can use to direct the lesson as he or she wishes



After seeing a demonstration of this program, one reviewer commented:
'(the program) won our unreserved admiration — and, if in everyday use it is as good as it appeared to be in demonstration, must be in the running to be rated the world's best piece of software to date.'

(Bryan Spielman, in *Computers in Schools*)

APPENDIX 4

Speciman pages from the MicroQuery Booklets

Published by the Advisory Unit for

Computer-based Education,1982.

Introduction to information retrieval

In many fields of human activity there is a need to collect data – representing items of information – and to manipulate or analyse this data in a number of ways. The handling of such data involves a number of operations. It has to be collected, organised and stored. Once stored, part or all of that information may be retrieved (selected) for analysis.

Consider a simple system designed to give the personal details of the pupils in a school. The system might record for each pupil his/her surname, initials, sex, birthday, form, subjects studied and home address. These details relating to a particular pupil would be collected together into one unit. Such a collection is called a *record*, and in our example the record contains seven items of information. In a manual system each record is conveniently stored on a separate card and each individual item of information might be identified by attaching a label to it. The layout of a typical card might be determined by having these labels preprinted upon it.

NAME: Rogers — INITIALS: D.G.
SEX: Female — BIRTHDAY: 30.6.60
ADDRESS: 19 St Albans Rd, Hatfield — FORM: 6th

SUBJECTS

1	Art	X	7	German	
2	Biology		8	History	
3	Chemistry		9	Maths	
4	Domestic Science		10	Needlework	
5	English	X	11	Physics	X
6	French		12	Technical Drawing	X

Under the general heading 'Subjects', all the subjects possible have been listed but only those pertaining to this particular student have been indicated.

The total amount of data stored will be determined by the number of cards present, and it is this collection of cards or records which forms what is called the *datafile*.

Space could be saved by removing the preprinted labels, and by coding the subjects with unique letters so that the letter T indicates that a particular student is studying Technical Drawing. This means we could reduce the above card so that it reads

ROGERS		DG
19 St Albans Road, Hatfield		
F	30.6.60	6
	AEPT	

but, we now need a master card to indicate the particular layout used. In our example there are seven areas of information, and the last area or bottom area may be further subdivided so that the information it contains represents the answer to the question

Which subjects?

We could define the layout of each data card by labelling each area as previously.

<table>
<tr><td colspan="2">NAME</td><td colspan="2">INITIALS</td></tr>
<tr><td colspan="4">ADDRESS</td></tr>
<tr><td>SEX</td><td colspan="2">BIRTHDAY</td><td>FORM</td></tr>
<tr><td colspan="4">SUBJECTS</td></tr>
</table>

The card will now contain a total of seven areas or fields. The size and shape of this card is immaterial providing we keep the information in the same fixed order. As far as the user is concerned the record can now be regarded as

ROGERS	DG	19 ST ALBANS ROAD, HATFIELD	F	30-6-60	6	AEPT

and we may give each FIELD a name corresponding to each label on our original card, that is, NAME, INITIALS, ADDRESS, SEX, BIRTHDAY, FORM, SUBJECTS.

Thus for this particular record the 'value' of the FORM field is 6, that of SURNAME is "ROGERS", that of SUBJECTS is "AEPT".

Sometimes a field is only permitted to contain a number, in which case the field is said to be 'numeric', for example, FORM is a numeric field. Alternatively, a field may be permitted to contain letters or a combination of numbers and letters, and in this case the field is said to be a 'string', for example, SURNAME and ADDRESS are both string fields. The importance of these distinctions will become clear when we discuss the formation of a query.

Having described the terms FIELD, RECORD and FILE, we see that a RECORD is composed of FIELDS and a FILE is a collection of RECORDS.

Let's assume that the records in our file are not in any particular order but that the information is stored on disks, either on a 380Z or on the PDP11 computer. We can now develop a scheme for selecting or extracting part of that system for further analysis. For example, we might require the names, initials and addresses of all those pupils in the school whose surname is SMITH, or a list of the names of all those in the sixth-form studying GERMAN. Both of these examples specify quite precisely what is required from the system, and looking at them in more detail we see that in both cases there is a *condition* specified together with an *action* to be performed if that condition is satisfied. It is important to realise that the condition and the action need not be related to the same field(s).

In the first example the *condition* is

SURNAME is "SMITH"

and the *action* specified is

PRINT NAME, INITIALS and ADDRESS

In the second example the *condition* is

FORM is 6 AND SUBJECT CONTAINS the CODE "G"

but the *action* specified is simply

PRINT NAME

In both these examples, every record in the file is tested against the condition, and for each record for which the condition is found to be true, the action specified is undertaken. This is similar to the way in which we would search manually records held on cards.

EXISTING DATAFILES

At the time of writing, the following datafiles are available, or will be available in the near future, on the PDP11/70 computer library:

Catalogue	Describes the current datafiles available
DATAFL	Information about data for QUERY
ASH41	Census Enumerators' records (1841) for the village of Ashwell in North Hertfordshire
ASH51	Ditto for 1851
ASH61	Ditto for 1861
ASH71	Ditto for 1871
ASTRO	Star data for stars brighter than visual magnitude 4
BOWLS	Illustrating the use of QUERY for administrative purposes
CAMBS	Settlements in Cambridgeshire
ESSEX	Settlements in Essex
ESTABS	Education Establishment Data (Hertfordshire)
FOOD	Foods with their various nutrients and costs as used in DIET
FRANCE	Places of interest in Burgundy
HAMLET	A copy of Act 1 of the play with each line as a record
HERTS	Settlements in Hertfordshire
IRAIS	Index of books with reading ages and subject matter
JOBS	A list of career possibilities and qualifications or interests
LEAH	Locally produced resource materials
OHERTS	Early settlements in Hertfordshire
PLACES	Places of interest in Great Britain
PTABLE	The elements of the periodic table
RURAL	Villages north of St Albans
SOM51	Census Enumerators' records (1851) for the village of Somerleyton in Suffolk

Further details of each datafile are available on the mainframe. To obtain up-to-date information, you should use QUERY itself. The command EXPLAIN will give information about a particular datafile and a special datafile is available (called DATAFL) which gives details of what datafiles are available and who to complain to if you find errors.

Users who do not have access to Mainframe QUERY can obtain up-to-date information on datafiles available by writing to the Advisory Unit or by looking on Prestel (page 2880506).

A simple QUERY condition

A SIMPLE CONDITON consists of three elements:

(a) FIELDNAME, (b) RELATIONSHIP and (c) TESTVALUE, where

(a) the FIELDNAME must be one which exists in the file being queried
e.g. ADDRESS

(b) the RELATIONSHIP must be appropriate to the type of the field
e.g. IDENT

(c) the TESTVALUE must be appropriate to the type of the field
e.g. "HATFIELD"

If the field is a numeric field, the TESTVALUE may be a number
e.g. 23.

If the field is a string field, the TESTVALUE may be a literal string, i.e. a sequence of characters enclosed in quotes
e.g. "FRED", "JIM SMITH".

(Note that spaces are significant in literal strings, this second example contains nine characters J, I, M, space, S, M, I, T, H in that order.)

A SIMPLE CONDITION is TRUE if the contents of the specified field bears the stated relationship to the testvalue.

Examples of SIMPLE CONDITIONS are:

NAME IDENT "SMITH"
TRUE if the NAME field is identical to the string of characters SMITH i.e. contains the five characters S, M, I, T, H and only those five in that order.

AGE EQ 23
TRUE if the contents of the AGE field is the number 23.

ADDRESS SUB "HATFIELD"
TRUE if the contents of the ADDRESS field contains the substring HATFIELD i.e. contains somewhere the eight adjacent characters H, A, T, F, I, E, L, D.

Combining simple conditions

We have defined a simple condition as consisting of three elements

FIELDNAME RELATIONSHIP TESTVALUE

We have shown that a multiple test value may be used so that a simple condition is also formed by

FIELDNAME RELATIONSHIP MULTIPLETESTVALUE

Several simple conditions may be combined by means of ANDs and/or ORs to form a compound condition. AND is an operator which binds more powerfully than OR. Brackets may be used to override this if required.

Consider the following problems:

(1) We require a list of all those children in the fifth-form who take needlework

FORM EQ 5 AND SUBJECTS SUB "N"

(2) We require a list of all children who were born in 1960 or on the first day of 1961

BIRTHDAY RSUB "60" OR BIRTHDAY IDENT "1-1-61"

(3) We require a list from which to select timekeepers for the school sports. They should either be in the fifth-form and taking maths or in the sixth-form

FORM EQ 5 AND SUBJECTS SUB "M" OR FORM EQ 6

If the user is in doubt he may add brackets although in this case they are not strictly necessary

(FORM EQ 5 AND SUBJECTS SUB "M") OR FORM EQ 6

(4) A list of pupils to help with a cookery demonstration are required. Members of the sixth who are either girls or who take Domestic Science are to be listed

FORM EQ 6 AND (SEX IDENT "F" OR SUBJECTS SUB "D")

Note: (a) Brackets are essential this time
(b) An inclusive OR is used so that a girl member of the sixth who takes Domestic Science would be matched

(5) Children taking languages who are in the third or fourth-form are required as hosts for a party from abroad.

(FORM EQ 3 OR FORM EQ 4) AND (SUBJECTS SUB "F" OR SUBJECTS SUB "G")

(6) Similar to (5) but with those in the fourth-form learning German and those in the third-form learning French.

(FORM EQ 4 AND SUBJECTS SUB "G") OR (FORM EQ 3 AND SUBJECTS SUB "F")

Brackets are not essential in (6) but are in (5).

Running the QUERY package

```
MicroQUERY    Permits interrogation
               of datafiles created
                or edited by QEDIT


                         Copyright (c) AUCBE 1981
v 7.2D
:
```

Query 'start' page, displays current version number and allows the user to continue, usually by stating an INFILE command.

MicroQUERY normally keeps the top 20 lines stable, with input and error reporting occurring only on the bottom four lines.

```
Values:

Title:

Query:

Print:


Add :
Mean:
Dev :

Format:  1        Infile  PTABLE
Width :  80       Outfile vdu
Go    : max       Sort  OFF
                  Archive

:
```

An INFILE PTABLE command has been given. The viewing page automatically displays the current values and a successful INFILE load puts the name PTABLE on the screen.

```
Structure:
=========
 Fields: 16                          Records: 92

  Properties of 92 natural elements


NUMBER       n-6   | DATE          n-4
ELEMENT      s-12  | DISCOVERER    s-33
SYMBOL       s-6   | ENERGY        n-6
MASS         n-7   | FORM          n-4
VALENCY      n-7   | MELT          n-7
OTHERV       s-11  | BOIL          n-6
PERIOD       n-6   | DENSITY       n-10
GROUP        s-5   | SHELL         s-5

:
```

When the STRUCTURE command is given a limited amount of data is shown about the present INFILE. This is one command which obviously removes the 'values' screen. More detailed information on any of the fields listed can be obtained by using the EXPLAIN command:

i.e. by typing EXPLAIN FORM

```
FORM
numeric   width, 4
A code rep. crystal form:

1. Cubic, face-centred
2. Cubic, body-centred
3. Cubic, diamond
4. Cubic
5. Hexag. & Hexagonal close packed
6. Rhombohedral
7. Tetragonal
8. Orthorhombic & Rhombic
9. Monoclinic

:
```

Showing the EXPLAIN text for the FORM field. Note that STRUCTURE and EXPLAIN both indicate field widths.

```
QUERY Allows the condition for matching
===== records to be specified.
Field operators: String: (string values
================           in quotes)
  IDENT   identical to
  SUB     contains the substring
  LSUB    contains the left substring
  RSUB    contains the right substring
  PRE     Precedes alphabetically
  SUC     Succeeds alphabetically
                   Numeric:
  EQ      equal to
  LT      less than
  GT      greater than
(Note that an N in front means the
opposite eg. NSUB means: does not
contain the substring.)
Logical connectives:
====================      AND      OR

:
```

Output given by typing the command HELP QUERY. This then gives detailed information on the type of operators and connectives permitted.

On-line HELP will always provide up-to-date information on the latest version.

```
Values:

Title:

Query: DISCOVERER SUB "RAMSEY"

Print: ELEMENT,DATE,DISCOVERER


Add :
Mean:
Dev :

Format:  1      Infile  PTABLE
Width :  80     Outfile vdu
Go    : max     Sort OFF
                Archive

:
```

The 'values' screen after valid QUERY and PRINT commands have been given; to find out the chemical elements discovered by Ramsey.

```
:ELEMENT        :DATE:DISCOVERER
--------------------------------------------
  HELIUM         1895 RAMSEY
  NEON           1898 RAMSEY & TRAVERS
  ARGON          1894 STRUTT & RAMSEY
  KRYPTON        1898 RAMSEY & TRAVERS
  XENON          1898 RAMSEY & TRAVERS

--- Searched: 92 --- Matched: 5 ---
:
```

A view of the screen after the GO command. Different options are available for where the output is to go and in what form. Here output is to the screen and in FORMAT 1. The QUERY was for:

DISCOVERER SUB "RAMSEY".

The output in this mode will provide 16 matches before the screen is cleared and the page started again. If another (controlled) output is required, a parameter is given to GO which stops output on a page after 'n' matches. The prompt 'continue?' appears and any key (except a colon) will resume searching. A colon interrupts and ends the search.

If the RECORD command is issued, all fields will be printed and the screen will scroll as shown here.

Note that in FORMAT 1 output to the screen is truncated to 40 characters, regardless of the WIDTH specification, the latter only being operative for printer or disk.

```
NUMBER         :54
ELEMENT        :XENON
SYMBOL         :Xe
MASS           :131.3
VALENCY        :2
OTHERV         :+4,+6,+8
PERIOD         :5
GROUP          :G0
DATE           :1898
DISCOVERER     :RAMSEY & TRAVERS
ENERGY         :1170
FORM           :1
MELT           :-111.9
BOIL           :-108
DENSITY        :0.005895
SHELL          :
----------------------------------------
Continue?
```

Using QUERY

These examples are taken from the PDP11. The format looks somewhat different on the 380Z, although the commands are the same. Note, what the user types is underlined.

```
LIBRUN QUERY <-----------------

QUERY Version 5.2
=====
An information retrieval package

    HELP or some other command

:INFILE HAMLET <-----------------
:TITLE What people said about Hamlet
:QUERY TEXT SUB "HAMLET" AND CHARCTER NIDENT "HAMLET"
:PRINT CHARACTER,TEXT,SPEECH
:GO
Please wait

Searching file HAMLET
For TEXT SUB "HAMLET" AND CHARACTER NIDENT "HAMLET"

What people said about Hamlet

 CHARACTER TEXT                                                SPEECH
 --------- ----                                                ------
 HORATIO   DAR'D TO THE COMBAT. IN WHICH,OUR VALIANT HAMLET,   48
 HORATIO   HIS FELL TO HAMLET.NOW SIR,YOUNG FORTINBRAS,        48
 HORATIO   UNTO YOUNG HAMLET.FOR UPON MY LIFE,                 59
 KING      THOUGH YET OF HAMLET OUR DEAR BROTHER'S DEATH       61
 KING      BUT NOW COUSIN HAMLET,AND MY SON?                   67
 QUEEN     GOOD HAMLET CAST THY NIGHTED COLOUR OFF,            71
 KING      'TIS SWEET AND COMMENDABLE IN YOUR NATURE HAMLET,   75
 QUEEN     LET NOT THY MOTHER LOSE HER PRAYERS HAMLET:         76
 KING      THIS GENTLE AND UNFORC'D ACCORD OF HAMLET           78
 LAERTES   FOR HAMLET,AND THE TRIFLING OF HIS FAVOURS,         138
 OPHELIA   SO PLEASE YOU,SOMETHING TOUCHING THE LORD HAMLET.   150
 POLONIUS  THAN A COMMAND TO PARLEY.FOR LORD HAMLET,           159
 POLONIUS  AS TO GIVE WORDS OR TALK WITH THE LORD HAMLET:      159
 GHOST     TO EARS OF FLESH AND BLOOD;LIST,HAMLET,OH LIST.     199
 GHOST     WOULDS'T THOU NOT STIR IN THIS.NOW HAMLET HEAR      205
 GHOST     O HAMLET,WHAT A FALLING-OFF WAS THERE,              207
 GHOST     ADIEU,ADIEU,HAMLET:REMEMBER ME.                     207
 MARCELLUS LORD HAMLET.                                        210

           Searched... 913
           Matched.... 18

Type HELP or some other command
:
```

Tells the computer to run the QUERY package

Each QUERY must start ... command

A second search through the file would be needed if complete speeches were required. Printing the speech number makes it possible

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