DOCUMENT RESUME

ED 216 678 IR 010 152

AUTHOR Miller, Allen H., Ed; Ogilvie, John F., Ed.
TITLE Bringing Computers into College and University Teaching. Papers Presented at a Symposium Held under the Auspices of the Higher Education Research and Development Society of Australasia (Canberra, Australia, November 19, 1980).
INSTITUTION Higher Education Research and Development Society of Australasia, Sydney. (Australia).
REPORT NO ISBN-909528-15-2
PUB DATE 19 Nov 80
NOTE 66p.

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Artificial Intelligence; *College Instruction; *Computer Assisted Instruction; *Computer Graphics; *Computer Oriented Programs; Foreign Countries; Higher Education; *Man Machine Systems
IDENTIFIERS *Australia

ABSTRACT

The use of computers in higher education teaching programs is discussed in 16 papers and reports. Applications of computers in teaching particular subjects including prehistory and anthropology, mathematics, Hindi, plant science, chemistry, language, medicine, drawing, statistics, and engineering are discussed in 10 of the contributions. The other papers address attitudes and barriers to the use of computing in teaching and learning, recent developments in hardware applicable to computer assisted instruction, interactive graphics and image displays, and artificial intelligence. A 105-item bibliography is included. (CHC)

BRINGING COMPUTERS INTO COLLEGE AND UNIVERSITY TEACHING

PAPERS PRESENTED AT A SYMPOSIUM
HELD UNDER THE AUSPICES OF
THE HIGHER EDUCATION RESEARCH AND DEVELOPMENT SOCIETY
OF AUSTRALASIA

Australian National University
Canberra
19 November 1980

Edited by

Allen H. Miller
Office for Research in Academic Methods
Australian National University

and

John F. Ogilvie
Office for Research in Academic Methods
and
Research School of Chemistry
Australian National University

Higher Education Research and Development Society of Australasia

Published by: The Higher Education Research and Development Society of Australiasia

ISBN 909528-15-2

Distributed for HERDSA by: Tertiary Education Research Centre,
University of New South Wales,
P.O. Box 1,
Kensington N.S.W. 2033
Australia

HIGHER EDUCATION RESEARCH & DEVELOPMENT

SOCIETY OF AUSTRALASIA

The general objective of HERDSA is to promote research and development in Higher Education. Membership of the Society is open to any person interested in that objective.

Further information regarding membership of HERDSA is available from the Secretary, HERDSA, C/- TERC, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033, Australia.

CONTENTS

INTRODUCTION

A. H. Miller

Computers as a supplement to college and university teaching were a direct outcome of earlier teaching machines, in which a student's response would determine the next sequence of learning activity. With the advent of computers it became possible to incorporate more sophisticated elements of control over the programs, but the high cost of hardware and lack of suitable software which could be used with different types of computers discouraged many potential users of computers for instructional purposes.

With the very substantial reduction in costs for all computers, and particularly with the advent of relatively cheap terminals and microcomputers, the opportunities for computer-assisted learning or computer-assisted instruction, as it is sometimes called, are much greater. Programming languages have also become simpler and special languages have been developed for computer-assisted learning. One of these, PILOT, will be briefly described in the papers which follow.

Another problem now being faced for the first time by some university and college teachers is a much less homogeneous student body. Institutions are admitting relatively large numbers of mature-age students, some of whom have been away from study for some years, and others with quite different background knowledge from that which is expected from students just leaving secondary school. Even among students entering university or college direct from secondary studies there is a much greater diversity of content covered in the school curriculum than was the case a few years ago. Investigations carried out by the Office for Research in Academic Methods (ORAM) in the Australian National University have shown that students entering first year physics and mathematics courses directly from secondary schools have covered a very wide range of topics before they enter the university, yet in these subjects many students claim that they are inadequately prepared for university study. With the advent of school-based curricula, it is possible that students from one school will have covered a completely different range of topics from students ostensibly studying the same subject in another secondary school. This diversity in backgrounds is to be expected in students entering tertiary studies in the physical sciences, the social sciences, or the humanities. Even foreign language students come with quite a wide range of prior knowledge and skills.

Tertiary institutions sometimes talk about the need for raising entry standards or for being more rigid in specifying pre-requisites for certain first year courses, but experience in recent years suggests that there has been a reduction in specific entry requirements, although it is claimed by some that entry standards have not necessarily suffered. It is this unpredictability as to the specific knowledge possessed by entering students, rather than any drop in general ability, which indicates the need for tertiary teachers to re-examine the potential of computer-assisted learning.

Realising that computer-assisted learning may provide a partial answer to some of the problems faced by university and college teachers, some members of the Higher Education Research and Development Society of Australasia (HERDSA) living in Canberra arranged a symposium in November 1980 for those interested in the theme *Bringing Computers into College and University Teaching*.

The symposium, which was attended by over sixty people from tertiary institutions in Canberra, was chaired by Mr Allen Miller, Director of the Office for Research in Academic Methods, and Professor John Ogilvie, Visiting Fellow in ORAM and the Research School of Chemistry. Facilities of the Australian National University, particularly in the Department of Statistics, the Computer Services Centre, the Computer Science Department, and the Office for Research in Academic Methods, were made available for the day's activities and for a follow-up session in February 1981, when a smaller number attended a workshop during which they learned to develop their own programs and put them on the computer.

Following the symposium, each of the sixteen invited speakers was asked whether s/he would like to contribute to a HERDSA publication on computer-assisted learning. Not all were able to accept this invitation, owing to prior commitments, but the response of those whose talks are included in this publication is gratifying in that it gives an indication of the range of topics covered and the rather unusual uses of computer-assisted learning in the Canberra College of Advanced Education and the Australian National University. It is not possible to include in this publication all the material presented at the symposium: the papers which follow are edited versions of the talks, the editing having been done mostly by the authors. In the case of those speakers who were unable to provide a paper for this publication, a brief summary of their presentation is given, based on notes taken during the day.

In making these proceedings available to the wider membership of HERDSA I would like to thank all who contributed to the success of the original symposium and the follow-up workshop. First to be mentioned are the speakers, all of whom are very busy people, who gave their time in preliminary planning sessions, in preparing and presenting their papers, and then, in response to a belated request, submitting a written version for publication.

Others who assisted include those who contributed to the general discussion during the symposium, those who submitted items for inclusion in the Bibliography, members of ORAM and the Computer Services Centre who helped ensure that all operations proceeded smoothly, and especially the Secretary of ORAM, Janet Healey, who typed all the material for this publication.

ATTITUDES AND BARRIERS TO THE USE OF COMPUTING IN TEACHING AND LEARNING

D. L. Overheu

INTRODUCTION

New technology always seems to be a fearsome and frightening prospect to those who are not involved in it. If we really think about it, however, we are all involved in some form of technology in one way or another. The meaning of 'technology' is as broad as all human endeavour, since it is not only the science of the industrial arts but the ethnological study of development of arts. In one sense it is about how man invents tools as well as how he formulates an organised body of knowledge about their habitual employment in useful work.

One of our more remarkable modern tools is the automatic digital computer. It would be difficult to find a more inappropriate name for such a tool because it immediately brings to mind visions of vast calculations on numbers. In fact, computers are used less for this purpose than for storing, retrieving, displaying, and changing any form of data from numbers through words to graphical shapes. Whether you want to be or not, you are part of the computer technology because it is all around you in everything you use, have available to use, or want to do. You cannot ignore it, it is not going to go away, and unless you do something about it, your students will know more than you do.

I am not trying to suggest that everyone has to become a computer expert before using a computer, any more than it is necessary to be a mechanic before driving a car. What I am suggesting is that we have a unique phenomenon that needs careful study and thought on the question of whether or not it has a place in teaching and learning.

Let me, therefore, distinguish between the use of computers in teaching and learning, and teaching and learning about computers. The former is often called 'computer-aided instruction' (CAI) or 'computer-aided learning' (CAL). On the question of learning about computers we must distinguish between studying computing as a professional pursuit in order to become a tool builder, and studying computing either to become a tool user or to understand its uses.

When we talk about barriers to the use of computing in teaching and learning we are most likely thinking about problems in the use of CAI. However, I think it is equally important that we think about problems in using computers to teach about their impact on our daily lives. Not many students choose to study computing topics for professional development and far more students leave studies before tertiary level than enter it. Even at tertiary level only a relatively small percentage of the whole have any exposure to computing studies. Somewhere along the educational line they need to be made aware of the effect computers may have on their lives.

TEACHING ABOUT COMPUTERS

I belong to a revisionist school in the computer world because I believe it is unnecessary to teach about the construction of computers or how they work in the first instance. Over a number of semesters now we have run a two-hour tutorial each semester aimed at achieving an attitudinal change in trainee primary school teachers. This may not seem much time to devote but it does meet its objective. It begins with a gentle introduction to the various specialised hand-held calculators for arithmetic training or word training, progresses to demonstrating games on a programmable calculator, and ends with a session during which the students work with computer terminals. In the latter case, games of increasing sophistication are presented. We have found significant attitudinal changes from 'I couldn't use a computer, I can't do mathematics' to 'Now I can see how I could use a computer in a teaching program'.

This, then, is one level at which we can try to overcome barriers by both involving teachers in simple uses and challenging them as teachers to make use of the technology in their curricula. We can now go a step further. Many readers will be familiar with the 'turtle' concept—a small robot device which can, under computer control, be made to react in a variety of ways through sequences of simple commands. It does not really need a computer and turtle to do this. Any member of the class can play the part, and simple instructions can be given in sequence one at a time.

In showing that people can control machines, we begin to break down another barrier or to change an attitude. This can be characterised as fear of being controlled by a mechanical device and lacking the knowledge either to control the device or to avoid being controlled by it. Hence, one avoids contact with such things so as not to run the risk of being controlled. Once it is realised how such devices can be controlled by sequences of very simple commands and how people can do the controlling, we see a marked attitudinal change.

Of course children react best to this approach, since they have no preconceived attitudes about pride or face saving—everyone laughs if the robot does something funny, even though they caused it to act in that way. Such lively interactions from children carry over to adults, and we again begin to break down barriers.

There is a point, however, when rather more must be understood about how computers function if we are to prepare students for life in a computer-driven society. At this point teachers at all levels have to be convinced about the importance of such concepts as privacy of information and protection of individual rights in order to want to know how use of computers affects these matters.

Currently in Australia a major study is being undertaken on what laws might be needed to ensure accuracy of personal data stored in a computer data bank, what safeguards might be available to people to protect personal information, and what penalties might be exacted. Because we have failed to bring the use of computers in society into our education system, we have failed the generations to follow. Too few people are concerned about these issues because they do not have the education to understand either the issues or their effects. The technological barrier has been permitted to affect attitudes to the detriment of free and informed discussion on vital issues.

TEACHING ABOUT USING COMPUTERS

Many years ago, in a university that shall be nameless, a computer was installed. The staff stayed away in droves until they found that their overseas colleagues did not want to talk to them if their data processing had not been done through a computer. Again, I find myself in a revisionist position. I do not believe it is necessary to know how a computer is made or how to write programs in order to *use* one in some discipline. Computing people have tended to foster the opposite view, and have consciously or unconsciously raised barriers. There is a level of use that requires no more than good instructions and simple input requirements. Nowhere has this been better demonstrated than in the games programs for microcomputers.

There is, of course, another level where some knowledge of mathematical or data processing concepts is needed so that appropriate data are fed in and appropriate interpretations can be made of results. Finally, there is also a level, even with such software packages, where the skill of the professional is needed to set up the package or to adapt it to a particular requirement.

All of this is teaching about using computers and, generally speaking, I think we do it rather badly. We fail to distinguish the levels of attainment necessary; we allow amateurs too much scope to establish or perpetrate bad attitudes or to erect new barriers, and we fail to control the standards within the computer field strictly enough. Anyone who can connect some components can offer a microcomputer for sale. Any novice programmer who can devise an operating system can complete the offering. Because the product is cheap it is bought and ultimately brings dissatisfaction — for good equipment and quality software are not cheap. Thus we establish a further barrier for the non-professional against use of computers in teaching and learning.

COMPUTERS IN EDUCATION

Let me reiterate the distinction between using computers in education for specialist purposes and using computers for CAI. It is the latter to which I now turn. Before talking about specific barriers to the use of CAI, I will discuss some general problems and what CAI seems to be attempting. We know that one barrier is time. About one hundred hours of preparation seem to be required to develop one hour of instruction. Now it might be thought that once this had been done, horrendous as it might seem, there would be no need for any change to that unit of instruction. If this were the case, we would have only one textbook on each subject, and no professional teachers but only trainers.

We seem to have overlooked the fact that CAI is really no different from any other teaching methodology. Good teachers are still required to produce the material and the curriculum. Constant revision is still required to keep up with the social development of the time. An understanding of aims and objectives for particular situations is still required. Unless these problems are solved we create barriers.

Let me distinguish some particular areas in which CAI seems to have some advantages. In doing so I shall point out the barrier-producing problems specific to the area while recognising that they are all subject to the criticisms I have just outlined.

PRACTICAL WORK

A common complaint is that students are subjected to insufficient drill in basic concepts. There are numerous CAI systems providing drill sequences in all areas of mathematics, grammatical structure of languages, or elementary concepts in science. A fundamental problem that continues to be ignored by manufacturers is symbolism. At some levels of instruction we raise significant barriers by demanding that a fraction be input as *a/b* while representing it graphically as $\frac{a}{b}$. Again, how many systems allow one to represent division by $a \div b$ or are able to represent the more common Greek letters or the integral sign?

I know there are ways in which this can be done but where a package makes it available, how easy is it to use the package? Have you ever tried to represent x^n for any reasonable value of n in these CAI systems? I believe this problem is one of the major barriers to any extensive use of CAI in mathematics. Since mathematical symbolism in the textbooks is not going to change, we had better think about how to do it on a computer display rather better than is being done currently. Developers of computer systems would do well to realise that we use over five hundred symbols in mathematical and scientific terminology.

TUTORIAL WORKSHOPS

The outline form of a tutorial workshop on any topic within a subject area tends to follow the format: present some elementary fact or definition, ask a question about an example involving the fact or definition, record the answer and time taken. Various escape sequences are also usually employed, such as providing a hint towards the solution or providing further information and testing if the answer to the first question was wrong.

We manage to produce some classic barriers for both the teacher user and the student user in some of these systems. If the originator of the system uses sequential access instead of random access files, the teacher user is often presented with an inability to insert new questions between existing questions consequential upon experience gained with the lesson. We find a situation somewhat like the uncontrolled use of GO TO statements and we very soon lose track of which addendum at the end belongs to which originating question. Of course sequential access is less demanding on disc space and easier to use than random access, so let's not worry about the barrier we set up in the teacher's mind!

Some of these CAI systems also provide quite elegant graphics capability, yet sometimes with surprising limitations. One with which I am familiar has an animation capacity for objects except that simple *lines* cannot be moved. I am still wondering how to represent motion of a relay contact in a simple diagram to illustrate elementary principles in relay logic.

For the student user, we should take great care to allow second thoughts as one would be able to do when using paper and pencil, yet how many systems do allow for this? Do we establish barriers in the student's mind by forcing him to continue when he knows the answer to the last question was wrong?

CONCEPT TESTING

Concept testing is an area that has much promise in CAI. It lends itself readily to the development of specialised terminals for particular types of testing and to various types of responses suited to the level of the user. Since paper-and-pencil concept testing does not usually allow a second-thought attempt at a question, we do not have the problem mentioned previously. It has the great advantage of removing human supervision and marking, thus introducing greater objectivity. Where tests are to be repeated, it must allow for some randomisation of question parameters so that answer learning is avoided. In arithmetic tests this is achieved by random selection of the numbers to be used. Anecdotal information seems to indicate an excellent attitude achievement, for both student and teacher, at all levels of its use.

Given the adequacy of the hardware and software for the task to be undertaken, I have not come across any specific barrier-raising problems. If any exist, I should be glad to hear about them. I believe this use of CAI is perhaps the easiest for both teacher and student. However, one might question its advantages over paper-and-pencil methods where the same degree of objectivity and remoteness from involvement by the tester can be achieved. The barrier is now more one of cost, and the best use of the computer might be in generating such tests.

SIMULATION OF EXPERIMENTS

There are many experiments in the natural sciences that would be too difficult, too dangerous, or too expensive to carry out in a real situation. Simulation of such experiments can often be adequately represented by a computer with appropriate graphics capabilities. Again, the opportunity is available for many repetitions of the experiment, thus assisting in the knowledge-gaining activity. I think it should be stressed that this can never be a substitute for carrying out real experiments; rather, it can be used to learn how to perform an experiment successfully, thus reducing the time taken, and perhaps also the cost, in a real situation. As well, the success rate in a real situation might be expected to improve.

This area is, perhaps, most useful in the secondary and early tertiary levels. However, we need to take care that simulation does not become a panacea for avoiding all live experimentation, otherwise we will begin to create barriers and wrong attitudes. We must never forget the Archimedian principle that science is based on experiment.

SPECIAL USES

There are several special uses of CAI that are only beginning to be considered or have not been in use for very long. These attack the co-ordination problems experienced by intellectually or physically handicapped children.* I personally believe this to be the most useful and rewarding area of CAI. There are instances available that

---

* See the paper contributed to this monograph by Iain Macleod, Computer Aids for Teaching Drawing and Recognition of non-Roman Characters to Tertiary Students (pp.51-3).

show a distinct gain by comparison with other methodologies. The problem is to provide an attention-holding activity, with demands and rewards, that has great flexibility both for adjusting the attainment level and for changing the presentation. Such a specification is uniquely suited to computer technology.

This is another area where I have yet to find barriers or attitudinal problems. Teachers involved in this work have great flexibility in looking for techniques that might succeed. The students themselves derive great satisfaction from being able to succeed in a world in which they know they are generally a failure. The training needed is arduous and time-consuming and needs a one-to-one relationship with the trainer—again, a specification admirably suited to the computer.

TEACHING THE PROFESSIONALS

I would like to say a few words about creating the people who build the tools. There is no doubt that CAI can be used just as well for this teaching function as any other. The barrier to its development has been largely one of time. Teachers of computing spend so much time developing computing exercises and examples that little time is left for CAI pursuits. Nor do they necessarily see any specific advantages, since they are only too well aware of the limitations of presentation and the cost of providing what is really needed. CAI in this context is best suited to elementary studies, where the student numbers are large.

We have, however, other unique barriers to its development. Quality CAI requires both quality computer professionals and quality teachers. From the computing side there are a number of high quality CAI systems that provide a framework for the teacher to operate within, yet they have not attracted teachers; one can only suppose the reason to be that the presentation appears to demand extensive learning about programming.

There are, correspondingly, a number of well-thought-out teaching schemes implemented on computers by teachers lacking professional computing competence. These appear cumbersome, unmodifiable, and clumsy to the computing professional. Thus barriers are established on both sides. One supposes the ideal would be a professional teacher who is also a computing professional, but even this may not be the answer.

It is more likely that we are faced with a typical computing problem. The more we try to generalise a CAI system, the more difficult it becomes to use, and this is not inconsistent with any generalisation of packages for particular activities. As I commented earlier, specialisation of a general-purpose software package invariably involves professional computing expertise. Any package of lesser dimensions is bound to have restrictions which the teacher must accept if it is to be used solely by teachers. It may be that this is one of the central problems that create the barriers against greater use of CAI.

CONCLUSION

I have ranged rather widely in this introduction, from the use of computers in teaching both about computers and for other subjects, to training computer professionals. Unfortunately the question of why CAI has been around so long and yet computers have not impinged on teaching and learning to the same extent as they have in other areas still appears unanswerable. I have speculated that the barriers might lie with presentation or display, ease of interaction, difficulty of setting up lessons, and fear attitudes. There is as well a continued cost barrier to achieving the type of presentation desired or the type of system required, although the latter is rapidly decreasing.

I continue to believe that currently CAI has its most effective application for physically or mentally handicapped children, for disadvantaged community groups, or as a specific training aid. I hope, however, that seminars such as this one will help us to expand into wider uses of computers in teaching and learning.

RECENT DEVELOPMENTS IN HARDWARE APPLICABLE TO CAL

Brian Stone

In this session Dr Stone addressed the difficult questions of *what* to choose and *how much* we can afford. The relative advantages and disadvantages of large computer systems compared with medium and small were also described. Among the main issues raised by Dr Stone was that while the cost of microcomputers has fallen dramatically, the cost of programming continues to increase at least in line with inflation.

He warned of the dangers arising from the restricted field of view which is presented by some enthusiasts. Any academic department discussing the possible introduction of computer-assisted learning should carefully examine the costs in terms of both money and time. Nevertheless, any increased use of computers for educational purposes should result in reduced costs for both hardware and software through an increase in the volume of microcomputers being manufactured, and through acceptance by teachers of standardised computer programs for some of their work.

INTERACTIVE GRAPHICS AND IMAGE DISPLAYS FOR CAI

R. A. Jarvis

INTRODUCTION

It is not surprising, given the richness of the visual world around us and our unique ability to appreciate it and derive vast amounts of information from it, that line graphics and imagery (both black/white and in colour) would be considered important as instructional aid resources. That the instructional aid apparatus happens to be a computer does not change this basic requirement for non-numeric display. The computer permits a degree of graphical interaction with the user/viewer which is hard to equal by any other means. This brief note describes the basic attributes of a range of image display devices and graphical input/output apparatus. Most of these are readily available for use with the variety of microcomputers on the market today.

INPUT DEVICES FOR POINTS, LINES AND IMAGES

The simplest device class for input of point and line data converts potentiometer derived analogue voltages representing X and Y positions into numeric quantities which can be stored and manipulated. The mechanical positions of the ~~potentiometers are set~~ or shifted by the operator. *Joysticks* arrange the X and Y potentiometers in a mechanical quadrature configuration to allow hand manipulation of a single stick to produce the X and Y signals simultaneously. Used in conjunction with an X-Y display of the input position point, the joystick need not be a linear device since hand/eye coordination is used to 'draw' the display line image. The *mouse and the tracking ball* are similar to the joystick in the use of potentiometer derived X and Y analogue signals. The mouse is pushed around on a hard flat surface; wheels arranged in quadrature rotate potentiometers to produce X and Y information. Lifting the mouse and replacing it at some other point on the plane surface does not alter its output, which varies only on rolling contact. A tracking ball produces the required X and Y signals when the user rolls a sphere, half hidden in the device, with the flat palm of his hand or by pushing it about with his finger. *Thumb Wheels* produce the X and Y signals separately and are less convenient to use.

A second class of graphical input device uses a drawing stylus in much the same way as one would use a pen on a writing sheet. One of the earliest devices in this class, the *Rand tablet*, uses a large number (1,000) of vertically and horizontally arranged conducting strips, separated by an insulating material, over a flat surface ten inches square. Each line carries its own identifiable code signal. The stylus picks up the signal of the conducting strip it is closest to in the vertical array and the horizontal array in turn. Pressure of the stylus point on the tablet is also signalled to the processor. The stylus signal is decoded to derive the corresponding X and Y position information which is then transmitted to the computer; only 'pen down' information need be stored. The *Sylvania tablet* uses a resistive sheet fused onto a glass plate. High frequency alternating current signals are applied to the vertical and horizontal edges of the resistive sheet, the vertical and horizontal signals being at different frequencies for identification. The phase information derived from the stylus is used to evaluate X and Y position. The active stylus can be positioned up to about a quarter of an inch from the tablet surface. Proximity of the stylus to the tablet surface and stylus point pressure are used to evaluate the 'intent' of the user in the context of the current X and Y data. A writing stylus on a thick pad of paper is a natural way of inputting graphical data and producing a marked sheet for future reference. If the tablet device is sufficiently linear (and this is the intent), predrawn sheets can be traced for computer input. An *acoustic tablet* uses an ultrasonic source on the stylus and linear arrays of microphones along a vertical and horizontal edge of the tablet surface. The sound travel time from the stylus to the microphone arrays is used to produce the required X and Y position. This type of tablet can be extended for three dimensional input of position data by adding a third microphone array in the Z direction. In summary, graphic tablets are generally linear devices which do not rely on visual feedback for accurate input of graphical data; they are used as naturally as pen and pad and are ideal for drawing and tracing input without the need of a display device.

Many computer users prefer a *light pen* to the other classes of graphical input devices described above. The degree of screen interaction made possible is its chief advantage. A photo-detecting circuit in a pen-like device picks up light signals from a display screen; precisely when this occurs must be translatable into position. This can be done in several ways. If the display screen is a raster device which is 'written on' by intensity modulated horizontal scans from left to right, and from top to bottom like a domestic TV receiver, the instant when the pen picks up a light signal pulse as the scan passes by with the pen pushed up to the screen (or near it) can be used to give position information by reference to the raster scan synchronisation timing signals. The part of the screen under the pen must, of course, be 'lit' or no 'strike' will occur; this means that the user's program must produce targets for the pen (a tracking cross is a particular type of target which can be moved around) or the whole screen can be light 'flooded' down to where the pen indicates a strike. If the display is an X-Y device with the user's program continually generating the brighter parts of the screen at a rate beyond that which would produce flicker, the timing of the pen strike must be related to the sequence-timing references of the program for position identification.

For low precision but convenient input/interaction, the interruption by a poking finger of one of a set of vertical and one of a set of horizontal light beams across the face of the display device can give direct position data, given that the interruptions of the particular beams are detectable by arrays of photosensitive devices.

Since the requirement for full image input as distinct from point or line graphical input is much less likely in a CAI environment, the subject, normally quite a complex one, will only be touched upon. For photographic transparency images, a raster scan by a minute spot of light is focused on the plane of the transparent film; the amount of light getting through (as measured with suitable photomultiplier electronics) indicates the transparency of that particular part being scanned at any instant. The position of the beam is used to index a two dimensional array of values of the corresponding transparency measure (converted to digital form). If a CRT (Cathode Ray Tube) device is used for the raster, the apparatus is called a flying spot scanner. Alternatively, a mechanically rotating and shifting drum can be used (drum scanner). Modest design modification allows for the scanning of opaque planar material. Multiple scanning with appropriate filters is used for colour material scanning. The need for acquiring active imagery from live three dimensional situations is met by using television cameras of the TV studio type (raster devices) or solid state cameras which are array devices which have better position stability and mechanical robustness. Since a TV camera produces a composite video pattern of the image fifty times a second and each frame may represent some 300,000 spatial positions, the intensity at each point being perhaps accurate to 1 part in 64 for each colour (if a colour camera is being used), a vast amount of information is produced at a considerable rate. Microcomputer interfaces are available to 'capture' a frame of video information on the fly and create an array of intensity values in memory. Once in memory the image can be manipulated and redisplayed but not in real time for any but the most trivial of operations unless specialised processor devices are used.

OUTPUT DEVICES FOR POINTS, LINES AND IMAGES

Output devices in this sphere of interest are easier to describe than the input devices of the previous section. There are basically seven types.

The crudest output device of graphics or imagery is the common hard copy device, whether a teletype or line printer. The position and type of standard alphameric characters can be manipulated to give low accuracy output graphs of various kinds. Also arrays of carefully selected and/or overprinted characters can be used to produce output images. A dot-matrix printing device for which each printed 'character' is created by selections of a number of print pins arranged in a small array (5 x 7, or 7 x 9, or whatever) can be used for high quality graphics output and also for medium quality black and white image output using half-tone techniques where the perceived darkness of a point on the image is proportional to the density of discrete dots in the vicinity. X-Y plotters and digital plotters can also produce a range of graphics and image output.

None of the output devices above can be used in an interactive way, and all are relatively slow in operation. The four remaining types of output device described here are all electronic devices capable of high speed operation. The direct storage tube is an X-Y output display CRT where a charge pattern is stored on a screen behind the phosphor layer; and this pattern is imaged on to the phosphor by a flood of electrons.

Since the charge pattern can usually remain for more than ten minutes, it is possible to 'draw' out to the tube sequentially, perhaps calculating the trace as one goes, and to see the partial and complete image without needing to have had the entire set of relevant position data in computer memory at one time. This aspect can be significant since storage tubes can have resolutions from 1000 x 1000 to 4000 x 4000 points, the latter representing 16 million bits of viewable information. However, the common direct storage tube devices on the market (e.g., Tektronix 4010 and 4015 series) do not allow partial erase of the screen; this makes dynamic interaction almost impossible. Usually, also, there is the restriction to a single colour and one bit of intensity information (ON/OFF). Refreshed CRT devices are of two kinds. The X-Y variety require the regeneration of the random scans associated with the point-and-line drawing sequence above 20 times per second to avoid flicker with relatively fast phosphors. Graphic output tables in the computer are scanned over and over again and a considerable load is put on the computer to maintain the image. However, interaction is simple with any of the graphic input devices described earlier, as these tables can be dynamically altered at the rate of repetition of the scan, perhaps during a small slice of time reserved for alteration. A raster-refreshed CRT is driven from a frame store which needs to have the storage capacity associated with the intensity and spatial resolution of the screen, not simply the complexity of a specific drawing or image (as in the case of the X-Y CRT). As memory is getting cheaper, these types of devices are becoming more popular. An added attraction is the compatibility of most available raster-refresh CRT devices with the technology of domestic TV equipment. If colour imagery is required with, say, a spatial resolution of 256 x 256 with 16 levels of intensity for each of red, blue, and green components, some 768000 bits of frame store memory are necessary. Interaction is achieved by reacting to an input device by altering part or all of the frame store information. The normal refresh function is often completed in the display system, relieving the main processor of this chore and making it available for other computations, including, perhaps, the gathering or manipulation needed for the next image. Finally, plasma panel devices consist of sheets of glass entrapping bubbles of helium/neon and other gas mixtures. These bubbles are excited into fluorescence by supplying voltage to grids in vertical and horizontal directions on the glass. A lower excitation voltage will maintain the glow after an initial higher voltage excitation signal. Thus some of the advantages of the storage tube are retained. Because the plasma panel is not an electron-beam device, it is not limited in size by the square-law driven requirements for high electron-beam accelerating voltages necessary for CRT devices. Some work is currently being done to allow for multicolour plasma emission. Mentioned only for completeness, the flying spot scanner and the drum scanner devices described earlier can be used in reverse for producing photographic images from computer output.

CONCLUSIONS

Luckily, despite the inherent complexity of some of the devices described above innovations in micro-electronics and the economies of scale have made most of these available for the microcomputer user at relatively affordable prices. Potential CAI developers would be strongly advised to consider seriously, amongst other things, the range of such devices available for any candidate machine before selection for purchase.

INTRODUCING PRE-HISTORY AND ANTHROPOLOGY STUDENTS TO THE USE OF THE COMPUTER

Graham Harrison

Problems encountered by Honours students in the Australian National University's Department of Pre-History and Anthropology were outlined by Dr Harrison. These included the rapid growth of the Department into one of the largest in the Faculty of Arts, a non-acceptance by older academics of new technologies, and a confusion between survey work, statistical analysis, computing, and computer-assisted learning. An unexpected problem was students' lack of familiarity with a typewriter keyboard, an essential element in any computer operations.

In order to overcome students' pre-conceptions as to what a computer can do, Dr Harrison provides his students with simple, well-documented program systems and instruction manuals. These should be as fool-proof as possible. For example, a large notice is required stating how to switch on and log in to the system, and where to find the RETURN button.

Students are taught the elements of three types of applications, namely, data-based management systems, statistical analysis, and word processing. As part of these applications they are taught the use of the Editor, how to run a program, and how to use the SPSS package.

THE MATHEMATICS LABORATORY AT THE CANBERRA COLLEGE OF ADVANCED EDUCATION (CCAE)

Jo Edwards and Jo Baskett

BACKGROUND

CCAE is a multi-disciplinary establishment, with six schools offering courses at the diploma, degree, graduate, and post-graduate levels. Students come to CCAE from Canberra and surrounding areas in NSW, and there are also significant numbers from elsewhere in Australia and from overseas. Over 50 per cent of the students are of 'mature age' and have had a break of some years since they undertook formal study. Even if a student currently resides in Canberra it is likely that his secondary schooling was undertaken elsewhere.

Soon after CCAE admitted its first students it was recognised that some students were having problems with their courses because of a lack of basic mathematical skills. In the early days of the College the students were mostly enrolled in Administration and Accounting courses, then as the College grew new courses made numeracy demands upon students and the range of problems widened. The College responded by offering bridging programs, both short courses and semester units.

The problems which many students have with basic mathematics are recognised in tertiary institutions across Australia; these institutions respond in ways which are determined by their own structure and that of their student population. CCAE decided that the response most appropriate for its situation was to replace the bridging programs by a mathematics laboratory, and this opened in 1978.

THE 'MATHS LAB'

The CCAE Mathematics Laboratory offers assistance to any College student having trouble with his course because of a lack of basic mathematical skills. The Lab was deliberately designed to be flexible in its response to changing courses, changing secondary curricula, and changing resources.

Many of the students seeking help from the Lab are of mature age, some already graduates, who have forgotten previously mastered skills, or who are baffled by new terminology. Since CCAE admits students from a number of different secondary education backgrounds, many younger students find that there are gaps in the basic knowledge which lecturers assume they have. With over sixty courses at undergraduate levels, the requirements of the courses are as varied as the backgrounds of the students. Needed skills range through: arithmetic, interpreting graphs, basic algebra, trigonometry, basic calculus.

The approach of the Lab is to diagnose needs individually, in terms of the course being taken and the current competencies of each student. Then the student is directed to individualised materials arranged as modules, supplemented where necessary by individual tutorial help, and tested for mastery at intervals.

Different starting points for each student and subsequent self-pacing mean that many students may be doing the same thing at different times; this is in terms of the material they are studying, their needs for assisted drill sessions and their attempts at mastery tests. There is virtually unlimited scope for computer assisted learning, computer assisted testing, and computer management of the overall activity.

WHY MICROS?

Funds were not available for a mini-system, and interactive use of the CCAE Computer, already overworked, was not a viable proposition. After some investigation we acquired a 48k Apple II microcomputer. The high resolution graphics and the fact that a number of institutions and schools were starting to use Apples were encouraging factors.

Numerous enquiries in Australia and overseas for available software gave disappointing results for various reasons. Often 'CAI' packages were found to be drill or practice sessions rather than concept teaching. Most packages at the level we need have been designed for primary or secondary school use and are just not suitable for adults. Still others, while looking promising, did not quite fit into our system. It soon became obvious that, as with the printed modules being used in the Lab, the majority of the material was going to have to be developed at the College.

MICRO SUPPORT FOR THE LAB

Work is proceeding in four different directions in developing the role of micros in the Lab. One direction is as an alternative form of teaching and expanding those concepts with which students are having difficulty.

Workshop sessions are often run in the Lab for students needing drill and practice on a particular topic. These are to be supplemented by more practice on the microcomputer, which will have the added advantage of being available for more hours than the tutor in the Maths Lab.

Another area of assistance is in the marking of mastery tests. A lot of tutor time is spent on marking work that is essentially correct, and when this is done by computer it frees the tutor for the individualised help for which the Lab was designed.

An overall computer management of the Lab would be very useful, with each student's program of work set up and marked off as complete.

PROGRESS

Due mainly to lack of time, there has been real progress in only one of the four directions. Attached printout shows part of the mastery test which was designed for the first module (Operations on numbers) which includes work on negative numbers, fractions, decimals and percentages.

The test needed to be interactive, randomly generated, with feedback given to the student on wrong answers. For this test it was decided to pre-format the question and randomly generate the numbers within bounds in each question. The test was designed, tried, modified, and has been subsequently used in the work of the Lab. The answers are marked as soon as they are input; if incorrect, the correct answer is given, and the total score and result displayed on the screen at completion. A printer output is also generated for the student, incorporating any questions incorrectly answered, the student's response, the correct answer, and also the total score and result. This means that if necessary the student may get individual explanation and tuition from the tutor.

This type of testing produced various responses from the students. Some felt that it was 'like a little friend talking to you' and others found it too impersonal. Obviously a lot of thought needs to go into the dialogue to strike a happy medium. Younger students familiar with computers were quite eager to be tested in this fashion and some even insisted on trying the test again to get a perfect score. Some older ones, unfamiliar with technology, felt they had enough to cope with catching up with study without having to sit down in front of 'THAT!', as well. For maximum benefit, then, the program will be altered to allow either for interactive use or to generate a printed test for a student with a separate sheet of answers for the tutor. It will be extended also to testing all the modules but the style will be changed. Instead of pre-formated questions for each test, there will be a bank of questions and various test types so that a particular type of test (for example, a test on exponentials and logarithms) can be generated beforehand for printed copies, or at the time for interactive testing. In this way, new test types may be quickly generated.

PROBLEMS

There has been slower progress in the other three directions.

A number of questions and difficulties have arisen, and while solutions have been found to some, others remain, and in some cases may be peculiar to our particular system. There is the continuing lack of software in the maths area and the time-consuming problem of writing our own. The biggest problem of all, however, is one of terminology. Most of the students using the Maths Lab are not Computing students — as already explained, often their basic skills may be rusty or they have had to learn new maths terminology. For the computers to be of use to these students they need to see the same notation on the screen as they will see in their text books *and to be able to input it from the keyboard themselves.* So expressions such as

$$x^3y^{27} \quad , \quad (x_1,y_1) \quad ; \quad \sqrt{x^3} \quad , \quad \int y^3 dy \quad , \quad \sum$$

and even fractions in the form

$$\frac{1}{2} \quad , \quad \frac{2x+1}{3y} \quad , \quad \frac{x^2+1}{x^3-x}$$

not only need to be seen on the screen (which isn't impossible but is not straightforward) but need sometimes to be input by the student.

It is not fair to ask them to use ↑ or ** for exponentiation or to use the notation (X(1),Y(1)) to represent a point on a line.

WHERE IN THE FUTURE?

First of all we hope to have more micros available to the students for more hours than the Lab is open at present.

Work is progressing on setting up random tests for all the modules and on setting example sheets for workshops run in the Lab. It is hoped that eventually this will be incorporated into a management system of the Lab with access to the central computer through the micros for storage of student records, reference to diagnostic test results and archiving of files.

Attempts will be continued to acquire more teaching modules suitable for adults — in the meantime, any spare time will be spent in designing and writing suitable mater al ourselves, particularly using the very good graphics capabilities of these machines.

THE FOLLOWING ARE COPIES OF QUESTIONS IN WHICH YOU MADE ERRORS.

****

MULTIPLY $\frac{3}{2}$ BY $\frac{4}{5}$

LEAVE ANSWER AS FRACTION BUT GIVE IN SIMPLEST FORM.
YOUR ANSWER WAS: 12/10

THE CORRECT ANSWER WAS: 6/5

DIVIDE 10/15 BY 2/3

LEAVE ANSWER AS A FRACTION BUT GIVE IN ITS SIMPLEST FORM.
YOUR ANSWER WAS: 4/5

THE CORRECT ANSWER WAS: 1

SIMPLIFY $\frac{3/4}{6}$

LEAVE ANSWER AS A FRACTION BUT GIVE IN ITS SIMPLEST FORM.
YOUR ANSWER WAS: 3/24

THE CORRECT ANSWER WAS: 1/8

SUBTRACT -3 FROM -7
YOUR ANSWER WAS: 4

THE CORRECT ANSWER WAS: -4

A HOCKEY TEAM WON 25% OF THE TOTAL NUMBER OF GAMES IT PLAYED.

IF IT WON 10 GAMES, HOW MANY DID IT PLAY?
YOUR ANSWER WAS: 2

THE CORRECT ANSWER WAS: 40

STUDENT NAME: JO BASKETT I.D.: 123
MODULE: A1 DATE: 11/5/81 TEST MARK: 13 RESULT: N

COMPUTER ASSISTANCE IN THE TEACHING OF HINDI

R. K. Barz

THE DEVANAGARI SCRIPT AND ITS COMPUTER PROGRAM

Hindi, the official language both of India as a whole and of six of the states that make up that republic, is written in a syllabary known as the Devanagari script. The Devanagari script has a very respectable antiquity in India, directly stemming from an earlier syllabary invented there more than two thousand years ago. In addition to Hindi, the Devanagari script is also used for Nepali, Marathi, Sanskrit, and numerous other languages spoken in India and the kingdom of Nepal. All told, over 300 million people express themselves in writing through the Devanagari script. As a native Indian form of writing that is perfectly suited to the phonetic structure of Hindi and other south Asian languages, the Devanagari script has been able to resist powerful moves made in the past to replace it with either the Arabic or Roman scripts. There is, therefore, no doubt at all that it will remain one of the world's five or six major writing systems.

In the light of the importance of the Devanagari script it is not surprising that there should be a strong interest in devising a computer program by which Devanagari texts might be reproduced rapidly and clearly. A pioneering attempt to create such a program was made a few years ago here at the ANU by J. B. Millar and M. C. Newey in the course of their research into arbitrary font printing systems (Millar and Newey, 1977). Meanwhile, W. Glover, a linguist also working at the ANU, was trying to find a way of printing a previously unwritten Tibeto-Burman language of Nepal called Gurung. Gurung speakers were already familiar with Nepali in Devanagari script and wanted the same writing system for their own language. There are, however, no Devanagari printing presses in Australia. Devanagari typewriters can be obtained here with difficulty but Devanagari typescript, an example of which is given below in Table I (Tables I, II and III were all produced by the ANU Devanagari program), is rather clumsy and ungainly and is not acceptable to the Gurung. The only recourse seemed to be a fully developed computer program and so one was set up by J. B. Millar and W. Glover (Millar and Glover, in press). At the same time I was faced with the same problem in printing teaching materials for my Hindi classes and in trying to put my Hindi textbook, originally produced in typescript, into a more satisfactory format. I am grateful to Bruce Millar and Warren Glover for introducing me to their Devanagari program and for guiding me in its use and also owe thanks to Arthur McGuffin for his patience in showing me, a complete novice, how to operate a computer.

The ANU Devanagari program uses the RT-11 operating system on a Digital Equipment Corporation model PDP 11-40 computer. The actual typing of a Devanagari text on the Tektronix terminal keyboard used with this computer is not a complicated procedure and requires only that the person typing the text memorise the pattern of correlation between each upper and lower case Roman letter on the keyboard and a particular Devanagari symbol. Thus, as illustrated in Table I, the Devanagari letters representing the Hindi word pronounced *pahale* ('first') are produced by typing the sequence 'kx,n'. The terminal screen will show the resulting word in Devanagari script only. The Devanagari program allows for words in Roman script to be inserted (see Table III) anywhere within a Devanagari text so that Hindi words and sentences may be given together with their English equivalents. In this way a bilingual text may be printed by means of the Devanagari program and the frustrating need for two typewriters to produce a bilingual text is avoided.

THE NATURE OF THE SCRIPT

The basic Devanagari script, which is displayed in the traditional arrangement of letters in Table II, has 54 symbols. Twenty-one of these represent vowels and 33 stand for consonants. Since the script is a syllabary each consonant letter always, unless combined with another sign or altered with a diacritical mark, stands for that consonant pronounced with the vowel short 'a'. The vowel signs are of two types: eleven of them represent a vowel standing alone or as the initial sound in a syllable, and ten of them (no symbol is needed for the inherent short 'a') are joined either before, behind, under, or above a consonant sign in order to indicate the vowel that is pronounced after than consonant. Words are then built up as illustrated in Table III. There is only one irregularity in the script as it is used in Hindi: a medial or final short 'a' is not pronounced, although the vowel is implicit in the script. This does not cause any problem in comprehension.

There remains one final intricacy in the script. Its originators had to overcome the problem, which arises in all syllabic systems, of indicating that two or, rarely, more consonant sounds are pronounced together without an intervening vowel. The solution hit upon was to form conjunct consonant signs. In most cases these are simply made up of the first half of one letter attached to the full form of a second letter, but at least six conjunct syllables are so changed as to be no longer analysable into their component parts (cf. the examples *kissa*, *minnat*, and *sodveg* in Table III). With these six signs the total number of commonly used Devanagari letters rises to 60. Sixty separate signs and a large number of conjunct consonant symbols do not cause any inconvenience in handwriting, but they do lead to obvious difficulties for a typewriter keyboard. It is the awkward methods for producing conjunct consonants that must be resorted to on the Devanagari typewriter that make Devanagari typescript so unattractive. Thanks to the flexibility of the ANU Devanagari program the computer is able to produce any conjunct consonant symbol just as it would appear in handwriting or print.

INSTRUCTIONAL USE OF THE DEVANAGARI PROGRAM

As I have just recently acquired the technical ability to operate the Devanagari program, it could be put only to limited use for my Hindi classes in 1980. Its primary role during that year was to produce weekly written assignments and vocabularies. This material will eventually constitute a substantial computer file that will allow more interesting assignments to be given in coming years. At present I am feeding into other files a mass of example sentences gathered from a wide range of works of fiction and non-fiction, including newspapers and magazines along with books, as well as sentences transcribed from taped conversations. These files will then be sifted for illustrative material for a new edition of my Hindi textbook, a task that would be very tedious and time-consuming indeed without the aid of the Devanagari program. Projects for the future which involve the computer include the production of texts that would otherwise be unavailable to students and the creation of a program for the printing of the modified Arabic script used for Urdu, another language taught in my department. Looking further into the years to come, I would like to develop a program on which students could practise Hindi sentence constructions. Such an instructional program could supplement ordinary classes in much the same way as do existing audio- and video-taped materials in the language laboratory.

REFERENCES

J.B. Millar and W.W. Glover. Synthesis of the Devanagari orthography. In press, *International Journal of Man-Machine Studies*, 1981.

J.B. Millar and M.C. Newey. An arbitrary font printing system. In *Proceedings of the Digital Equipment Computer Users Society*, 1977, pp.1641-1647.

The example sentence in Table I is from Abhimanyu Anat, *Lāl Pasīnā*. New Delhi, 1977, p.28.

TABLE I

Hindi text as typed on the Tektronix terminal:

kx,n t,f dfl-z; ,ld pj,g sxlL' eL ,dgf gxlL ,bvL yL .

Hindi text as received by the computer:

प ह ‘ल त ‘ा म ा ि र श स ’म उ स ‘न क ह् ी भ ी

“म न ा न ह् ी ‘द ख ी थ ी।

Hindi text as it appears on the terminal screen:

पहले तो मारिशस में उसने कहीं भी मैना नहीं देखी थी ।

Hindi text as printed by the computer:

पहले तो मारिशस में उसने कहीं भी मैना नहीं देखी थी।

Hindi text in Roman transliteration:

pahale to mārishas mẽ usne kahī̃ bhī mainā nahī̃ dekhī thī.

English translation:

He had never before seen a mynah anywhere in Mauritius.

Hindi text in typescript:

पहले तो मारिशस में उसने कहीं भी मैना नहीं देखी थी ।

TABLE IX

The Devanagari Script

Independent vowel signs:

अ आ इ ई उ ऊ ऋ ए ऐ ओ औ

a ā i ī u ū ṛ e ai o au

Combined vowel signs:

ा ि ी ु ू ृ े ै ो ौ

+a +ā +i +ī +u +ū +ṛ +e +ai +o +au

Consonant signs:

क ख ग घ ङ

ka kha ga gha ṅa

च छ ज झ ञ

ca cha ja jha ña

ट ठ ड ढ ण

ṭa ṭha ḍa ḍha ṇa

त थ द ध न

ta tha da dha na

प फ ब भ म

pa pha ba bha ma

य र ल व

ya ra la va

श ष स ह

sha ṣa sa ha

The Devanagari Script as a Syllabary

क = ka + म = ma, कम = kam less

का = kā + म = ma, काम = kām work

आ = ā + म = ma, आम = ām mango

नमक = namak salt नामक = nāmak named इ = i, इनाम = inām reward

कि = ki, किसान = kisān farmer किस्सा = kissā story मिन्नत = minnat request

ई = ī, ईमान = īman integrity नमकीन = namkīn salty

मामा = māmā maternal uncle मामी = māmī maternal aunt मोम = mom wax

मौका = maukā opportunity ओम = om a sacred word

मैना = mainā mynah bird मुमकिन = mumkin possible

ओस = os dew मृग = mrg deer एक = ek one

केला = kelā banana

सो = so द = da द्व = dva द्वे = dve द्वेग = dveg

सोद्वेग = sodveg restless

USING COMPUTERS IN TEACHING PLANT SCIENCE

E. G. Brittain

INTRODUCTION

My use of computers in the teaching which I undertake falls into four sections, the first two utilise a main-frame computer, the second two make use of a microcomputer.

UNIVAC 1100-82 MAIN-FRAME

1. Preparation, maintenance and production of lecture semi-notes.
2. Operation of a population model for use in a practical class.

TRS-80 MICROCOMPUTER

3. Data reduction for a practical experiment.
4. Back-up operation of the model mentioned at 2.

LECTURE NOTES

In the 1974 academic year I first produced and distributed to my classes a full set of semi-notes. Until then I had been unwilling to issue typed notes, believing that the inflexibility of the methods hitherto available for their preparation would result in my course failing to develop as rapidly as the advance of knowledge in the field of plant physiology demanded.

The availability of a document processor on the Univac, along with a powerful text editor and good facilities for storing the material and for printing it out, made it feasible to produce notes which could be updated freely and easily each year. The production of notes for distribution has also had a strong disciplinary effect on my lecture preparation. My professional competence can now at any time be examined by anyone who acquires a set of the notes. This is in marked contrast to the situation which obtains when the only written record of the course exists in the lecturer's private scrawl and in the dubious versions written in haste by the attending students. The improvements in precision are considerable.

During the years since 1974 word processors have overtaken this use of the computer to a very large degree, although the power of the text editor is still superior to the capacity of at least the ordinary word processors.

POPULATION MODEL

The population model contains four differential equations of significant complexity and having no analytical solutions. Their dynamic development, as successive solutions are obtained numerically and built back into the equations as parameter values, describes the behaviour of the model.

The model is implemented in FORTRAN. It represents two plants which are in competition with each other and two parasites, one specific to each plant. Provision exists for harvesting the plants and for spraying the parasites and there are associated costs for those operations. The students operate the model interactively in attempts to devise strategies which are aimed at certain set goals. In doing this, the students learn the complexities of the behaviour of a multi-component model when it is manipulated. Insofar as the model represents real life, they also learn something of the behaviour of real systems under management. At the same time the philosophy which underlies the use of models, which enables 'experimentation' in circumstances where experimentation may not in fact be possible and which permits judicious simplification, becomes apparent.

DATA REDUCTION

One of the experiments in my practical course needs to be carried out in order to keep the course abreast of an important technique which is widely used in research in this field. Unfortunately the raw data obtained have to be taken through a complex calculation before meaningful physiological measurements are obtained. In most research laboratories the experimental equipment is connected on-line to some kind of computer so that the computations are done in real time and printed out at the operator's console.

It is not feasible to do this in the class situation, both on the grounds of expense and also because it would bypass a great deal of the learning process involved in the exercise. Instead the raw data are recorded on a simple multi-channel chart recorder and the figures are then typed into the microcomputer by the students. Intermediate results are presented and the student is led through the calculation in a logical and understandable pathway. At the same time the tedious labour is removed by the computer. Programmable calculators have been tried here, but found unsatisfactory on account of their inability to provide textual messages and prompts, which are essential to provide comprehension.

MODEL

The model described above is also implemented on the TRS-80 in BASIC. Its operation is slower than on the Univac 1100-82, but provides useful backup against the possibility of down time during class, and also permits students to do extra work outside class time.

MICROPROCESSORS IN CHEMISTRY

Cliff Henderson and Ben Selinger

INTRODUCTION

Chemists are intrepid model builders. They need models because the things they deal with—atoms, molecules, bonds, etc.—are too small to observe. Chemists, like lawyers, often argue their subject by analogy (i.e., precedent from previously known behaviour).

Consequently the learning of chemistry involves developing the craft of model building and simulation. Chemistry also involves much calculation. This can dominate areas of the subject to such an extent that the chemistry cannot be seen because of the calculations. These calculations wrongly become an end in themselves.

These then are some reasons why both analogue and digital computers are beginning to be seen to have an important role in the learning of chemistry.*

ANALOGUE

We have had a decade of experience in analogue computer simulations[2-5] which have formed an effective, self-learning, self-paced 'practical' unit. This unit was based on the classic paper by Tabbutt[6] but was then greatly expanded.

Use of the earlier analogue computers required a background knowledge of electronics and circuit theory. Indeed, we found analogue simulation a useful way of introducing instrumentally relevant electronics to chemistry students and developed ways of doing this without much of the usual formidable groundwork (*cf.* Biochemistry with Chemistry).

The feedback system is the essence of analogue simulation. Feedback is a concept which is fundamental to the understanding of basic

---

* In considering the whole area of computer aided learning (CAL), there is to be found a uniform assessment throughout the educational literature that the real problems are in the software area. This is mirrored in the Academy report.[1] It is argued that a typical one-hour lesson could involve well over one hundred hours of program development. Several languages have been used for writing courseware, but standardisation is slow in coming. In the hardware area, microcomputers offer fast and predictable response times, which removes the frustration of the long or variable response found with time-shared systems. The rapidly increasing standardisation, popularity, and availability of microcomputers (including in the home) will allow students to borrow or copy discs for out-of-school use. *In our view, the future of CAL lies with the dedicated microcomputer.*

In this paper, however, we are not concerned with the traditional CAL. We wish to discuss the use of microcomputers for *simulation* studies.

processes in biology, ecology,[7] engineering systems, social systems,[8] and even the process of science itself.[9] Analogue simulation has the power of *generalisation*. The eigenfunction solutions to the wave equation in quantum mechanics could also have been the aerodynamic oscillations of an aircraft wing. In both cases, the need for mathematical manipulative skills is greatly reduced in comparison to analytical solutions—with a corresponding decrease in apprehension. *Physical* control of variables (i.e., by turning a knob) can be more satisfying than *arithmetic* control.

However, in the more recent analogue computers with microprocessor control units, much of this pedagogic purpose has been lost.

DIGITAL

The trend towards small, dedicated digital computers using microprocessors was a natural one. While not replacing the special advantage of analogue machines (particularly with respect to differential equations met in areas such as chemical kinetics and quantum mechanics), they are nonetheless much more versatile, more accurate, and more convenient. They have the same attraction of interaction. They do, however, lack the freedom of innovation on the model beyond what has been foreshadowed in the programming (to a greater or lesser extent) —unless the user is a skilled programmer. To coming generations of students, computing will no doubt be second nature.

> 'Arithmetic' is so familiar to us nowadays that we forget how hard it was to multiply large numbers before the invention of Arabic numerals. The Arabic system is one of the greatest achievements of the human intellect, and is central to the whole realm of quantitative science.
> This Arabic system has two properties, descriptive and manipulative. The descriptive property provides a compact notation for large numbers; thus any number between 1 and 10 million can be written as a string of just seven symbols. ... The manipulative property is that, using this compact notation, we can still carry out all the operations of arithmetic. What a remarkable case of having one's cake and eating it![10]

A world without personal microcomputers will be as hard to imagine for the new generation of students as a world without arithmetic is for us.

THE TASK

In choosing the areas to develop, our criteria were as follows:

1. the prospective task must be performed better by the microcomputer than by other, traditional means;
2. the output should be dynamic;
3. the task should be interactive and allow modification by the student.

In a sense, the chemical problems had to be made as attractive as the computer games whose fascination is already legend.

From a large number of attempts a few tasks were successfully completed. A major problem with most realistic simulations (in our case with a Challenger-Ohio Instruments microcomputer) is that they run too slowly in BASIC but are too complex to write comfortably in machine code. A compromise is reached in writing critical routines in machine code (leaving the rest in BASIC). A better approach is to use a compiler program to produce machine code programs from programs written in languages such as FORTRAN or PASCAL.

Possibly one of the most fundamental arithmetic functions in physical chemistry is the negative exponential. Phenomenologically it describes the decay of radioactivity of an atom, the time dependence of luminescence decay of a light-emitting species, the kinetics of a first-order chemical reaction, the (approximate) change in density of the atmosphere with increasing height above sea-level, the decrement in light intensity as light passes through an absorbing medium, and so on. Theoretically, the negative exponential is the basis of the Boltzmann distribution of the population of quantised energy levels as a function of energy.

$$\frac{N_i}{N} = g_i \exp^{-E_i/kT}$$

[N_i the population, E_i the energy and g_i the degeneracy of level i; k Boltzmann's constant, T the absolute temperature, N the population of the zero energy level]

EINSTEIN SOLID

In an Einstein solid the atoms are represented by an array of oscillators possessing uniformly spaced, quantised energy levels with an assumed zero ground level.

Initially each oscillator has one quantum of energy and transfer of this quantum occurs according to the following algorithm.[11] An oscillator is selected at random. If it possesses at least one quantum of energy, then one quantum is transferred to another randomly selected oscillator. This process continuously updates the distribution histogram.

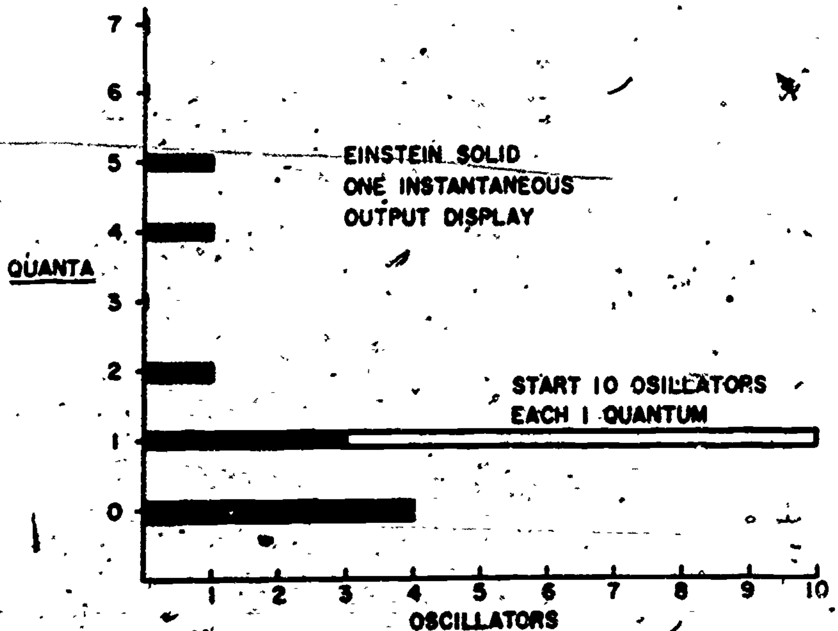

Figure 1. EINSTEIN SOLID

The more oscillators there are in the array, the less violent are the fluctuations about the mean exponential decay.

NEGATIVE EXPONENTIAL DECAY

If one takes a time dependent process, then a *deterministic* model assumes that at any given time the rate of change of population is proportional to the population at that time.

$$\frac{dx}{dt} = -kx$$

This equation predicts an exponential decay of population size with time, and that the population at any time is fully determined by both the initial condition (x at t = 0) and the rate coefficient k. That the solution is in general non-integer is unrealistic.

A discrete model assumes that the population can decrease only by integer quantities. The computer model is based on the distribution of times between successive events; these are distributed according to the probability density function

$$f(t) = \lambda e^{-\lambda t}$$

where λ^{-1} is the average time between events. For processes governed by f(t), an appropriately distributed variable is

$$t = -\log(R)/\lambda$$

where R is a random number uniformly distributed on (0,1) and t is the time between two successive events. For non-linear processes such as, for example, the modelling of the behaviour of epidemics (second-order kinetics), discrete models are essential because the deterministic model gives no answer in the sense that epidemics die out (are self-limiting). This is a probabilistic function of initial population size.

The use of stochastic models is a compromise between deterministic and discrete approaches. An outstanding textbook,[12] which is both a cultural and intellectual delight (quite unexpected in the world of technology), defines epidemiology as the diffusion of disease, and provides such delectable examples as a 'Brief History of Syphilis' followed by the 'Sailor—Prostitute Problem'. The book never ceases to be a constant source of inspiration over a wide area of computing.

NMR SIMULATION

An increasingly popular method of identification of chemical compounds is nuclear magnetic resonance spectroscopy (NMR). It is possible to predict the spectrum that a particular molecule should produce. At its simplest level the input consists of the number of protons, their chemical shift parameter and the coupling constants between protons.[13] A typical spectrum is shown below (Fig.2). Selected spectral regions can be expanded. The Lorentzian linewidth of the resonances, the chemical shift, and the coupling parameters can all be varied to provide a closer match to the real spectrum. The effect of these changes on the spectrum is instructive.

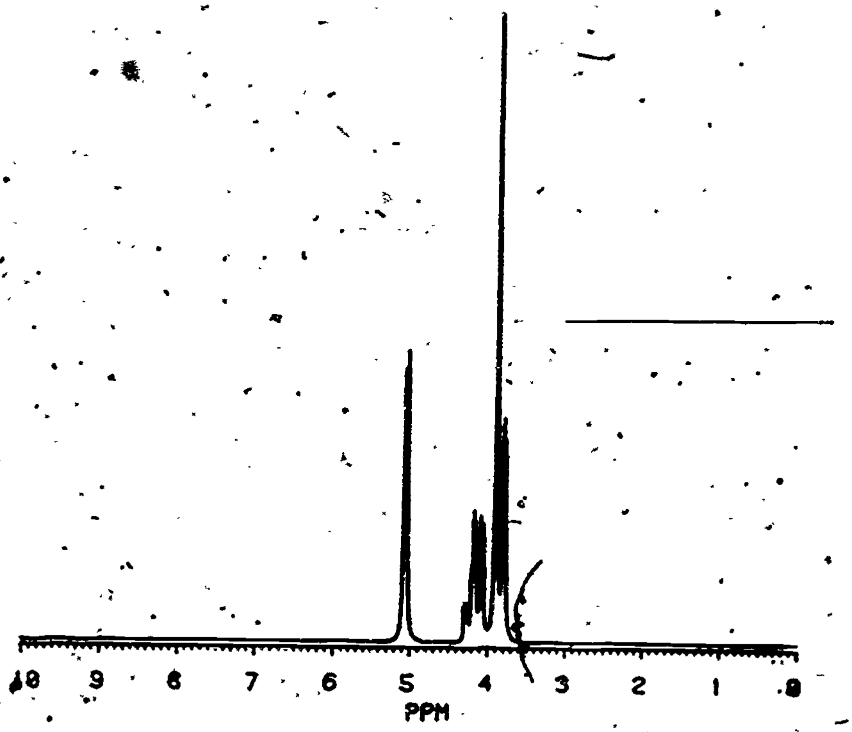

Figure 2. NMR SPECTRUM

Other complex instruments that have been successfully simulated on a microprocessor include the mass spectrometer. At La Trobe University, each student is given an individual digitised mass spectrum on a plug-in memory chip which constitutes their unknown sample compound for analysis. The instrument simulator then drives a chart recorder to produce a spectrum in the same way as the real instrument at a cost of $100, compared to at least $10,000 for a cheap real instrument.

FOURIER TRANSFORM

Fourier transforms have invaded the far corners of chemistry, from x-ray crystallography, interferometric infrared spectroscopy, Fourier transform NMR, and even quantum mechanics (wavefunctions in terms of momentum and position). A fast Fourier-transform algorithm[16] can easily be managed on the microprocessor, again with visual output of the effects of truncation, exponential convolution and sampling frequency. (see Fig.3).

THREE CONTOUR PLOTTER

This program allows a three-dimensional function to be plotted realistically on a phase surface. Atomic and Molecular Orbitals are an obvious chemical choice for such a plot; an example is given in Figure 4.

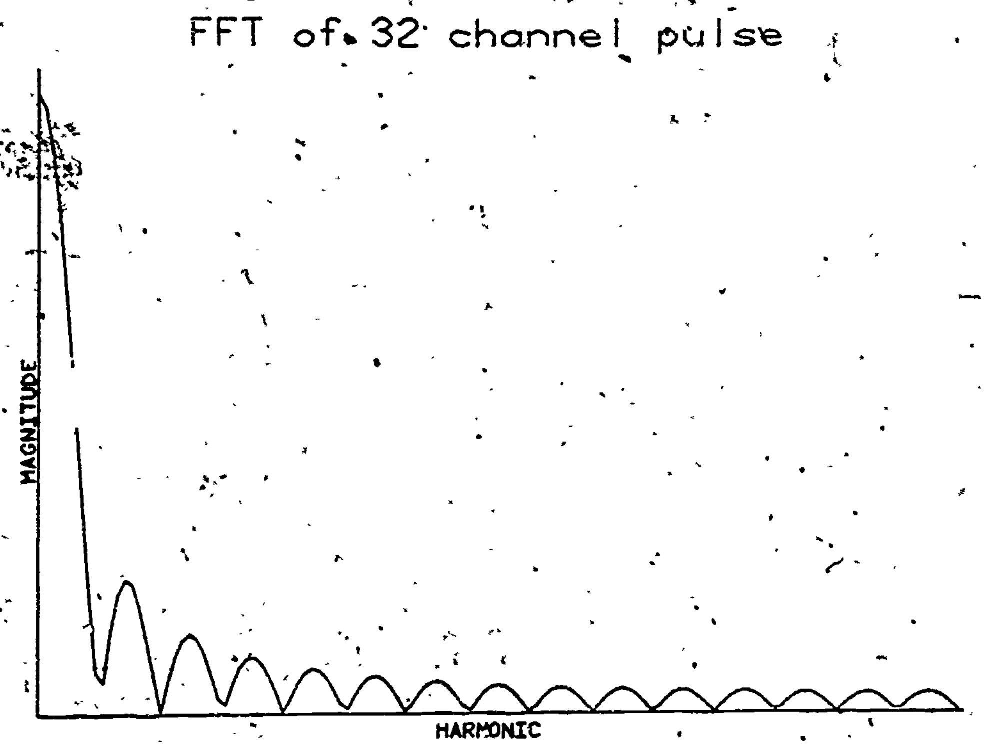

Figure 3. FAST FOURIER TRANSFORM

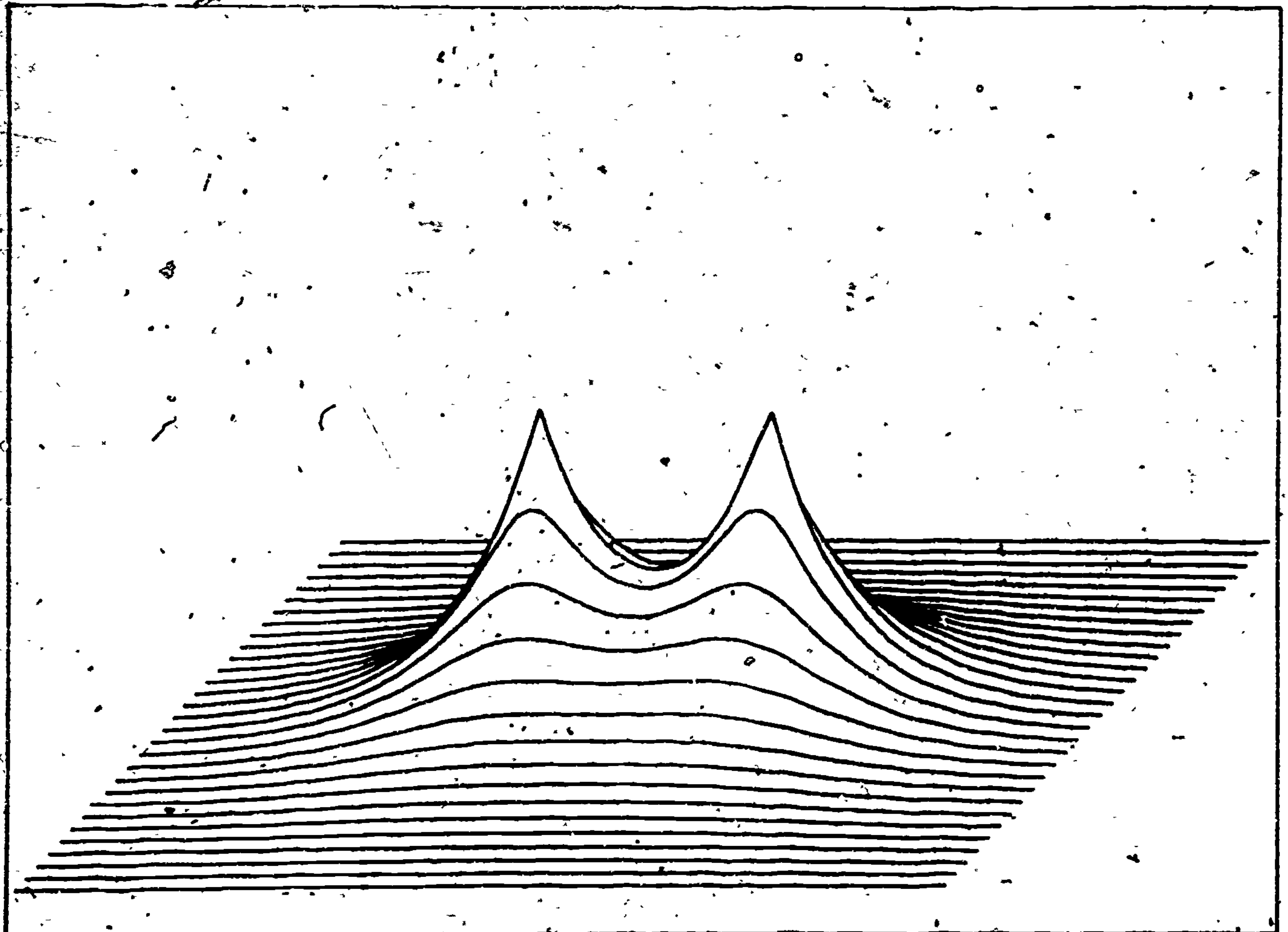

Figure 4. MOLECULAR ORBITAL OF HYDROGEN

SIMPLEX DATA FITTING

For the many problems of data analysis that are currently performed on computers, the use of a simplex for non-linear least-squares fitting is one of the most powerful and visual means.

A model function is fitted to the data with a simplex[15] which is basically an n-dimensional 'triangle' situated on the landscape of chi-square space (the sum-of-squares difference between the model and the data for a particular set of parameters). A simple set of instructions sets the simplex off, reflecting its highest point across the 'opposite' side so as to search out the global minimum on the landscape. Several additional instructions are needed, both to keep the simplex out of trouble and to locate the minimum accurately.

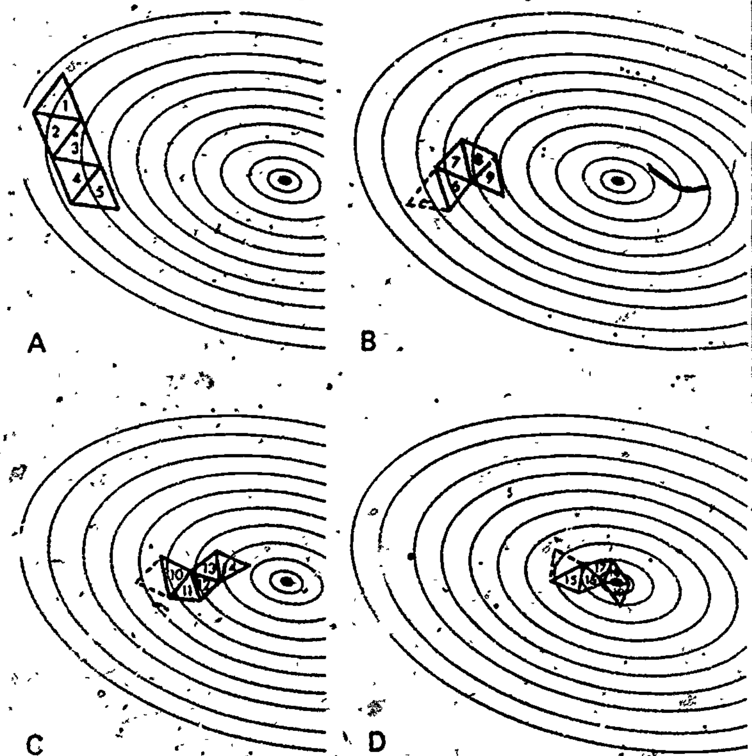

Figure 4(a). SIMPLEX

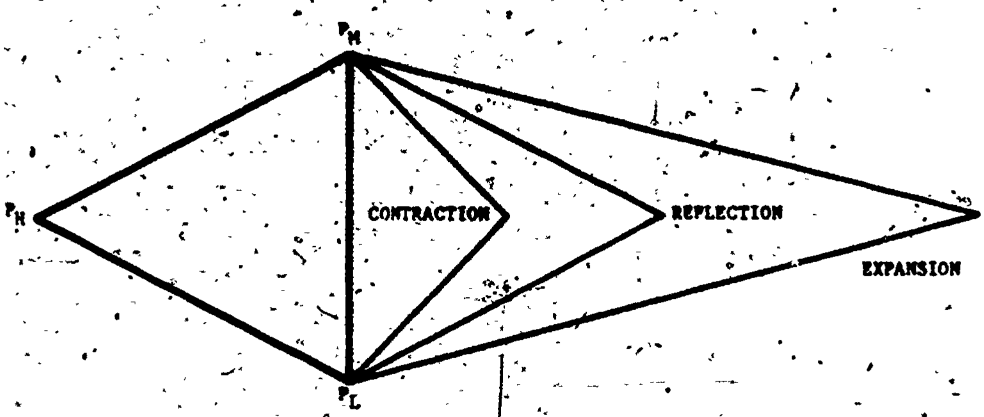

Figure 4(b). SIMPLEX OPERATIONS

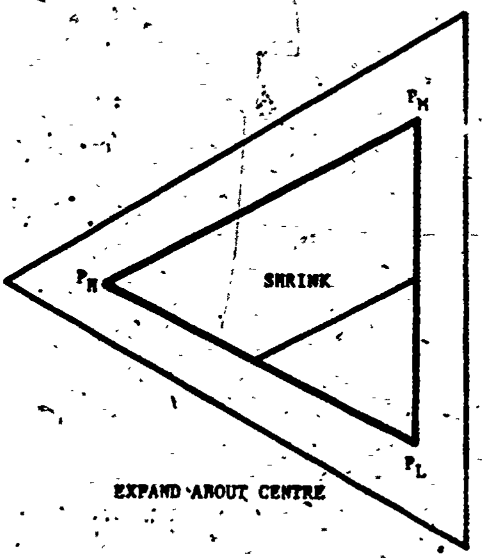

Figure 4(c). SIMPLEX NEAR THE MINIMUM

CONCLUSION

Further details of this work are available in

> C. N. Henderson, Microprocessors in chemistry. MSC thesis (and video taperecording), Australian National University, 1981.

For further reading in the area, see the section on Chemistry in the Bibliography (pp.67-9).

REFERENCES

1 *The impact of microprocessors on industry, education and society.* Australian Academy of Science Forum: Report No.16, 1980.

2 B.K. Selinger (co-ordinator). *Simulations with the EAI 180 electronic analogue computer; Physical Chemistry Unit C06.* 1st ed., 1970.

3 B.K. Selinger. *Simulation of chemical systems and the EAI analogue logic computer.* EAI Associates, 1973.

4 B.K. Selinger. Analogue computers in teaching physical chemistry. *AVCC Education Newsletter*, 2/71, p.3.

5 P.R. Nott and B.K. Selinger. A simple rule underlying kinetics. *Journal of Chemical Education*, 1972, 49, 618.

6 F.E.J. Tabbutt. The use of analog computers for teaching chemistry. *Journal of Chemical Education*, 1967, 44, 64.

7 A.N.D. Auclair, G.J. Birch, C.N. Henderson and B.K. Selinger. Simulation of mineral cycling in *Eucalyptus populrea* woodlands using an EAI 1000 analogue computer. CSIRO Reports, 1979.

8 Jay W. Forrester. Counterintuitive behavior of social systems. *Technology Review*, 1971, 73 (3), 1 (Alumni Association of MIT, Mass., USA 02139).

9 J. Sparkes. What is this thing called science? *New Scientist*, 15 January 1981, p.156.

10 J.M. Hammersley. The role of probability in the natural sciences. In *Chance in nature*, P.A.P. Moran (ed.), Australian Academy of Science, 1979, p.6.

11 J. Ogborn. The Second Law of Thermodynamics: a teaching problem and an opportunity. *School Science Review*, 1976, 57 (1201), 654.

S. Wiley. Thermodynamics of Ising Lattices. In *Computers in Undergraduate Science Education Conference Proceedings, Chicago, Illinois, 1970*, R. Blum (ed.), American Institute of Physics, 1971.

J.M. Ogborn, F.R.A. Hogood and P.J. Black. Chance and thermal equilibrium. In *Computers in Undergraduate Science Education Conference Proceedings, Chicago, Illinois, 1970*, R. Blum (ed.), American Institute of Physics, 1971.

12 W.R. Bennett. *Scientific and engineering problem-solving with the computer.* Prentice Hall, 1976.

13 J.R. Wright and J.L. Robinson. Use of general purpose microcomputers to synthesize hypothetical spectra for NMR recorder. *Journal of Chemical Education*, 1979, 56, 643.

14 W.D. Stanley and S. Peterson. Fast Fourier transforms on your home computer. *Byte*, 1978, 3 (12), 14.

15 J.A. Nelder and R. Mead. A simplex method for function minimization. *Computer Journal*, 1965, 7, 308.

CAI IN THE STUDY OF LANGUAGE

J. R. Trotter

A suite of computer programs has been developed for use in a course on the psychology of language at the Australian National University. A student may work privately at a video terminal, or at a teletype if hard copy is desired. Alternatively a portable terminal connected to a large-screen monitor provides displays for class work, with students taking turns as user. Communication with a user is in English, and absolutely no knowledge of computers or of computer or data languages is required.

A master program provides a directory to items. Each item gives explanatory text, in some cases of considerable length, taking a long time to print at teletype speed. But a user can opt to suppress exposition. A manual ('YC32 CAI ANU', obtainable from the author) contains specimen printouts of all the items, and with this to hand a student can avoid undesired waiting time at the terminal.

One program lets the user design a text, a spatial array of characters, as either (i), a purely decorative pattern, or (ii), an ordinary string of words, or (iii), an original decorative pattern, or intelligible string of words whose lines, followed in a certain order, spell out a hidden message. Another gives exposition and exercises on ways of discussing text: by quotation, or by reference to a figure or to an item in a table. Fifteen programs illustrate, in their ongoing printing behaviour, some of the dozens of kinds of generation that the course distinguishes. These are typically ill-distinguished in the literature, and none is the non-temporal generation involved in a mathematical theory or a grammar, and none is a likely candidate for a model of a person speaking or preparing to speak.

One program prints a sequence of ever more detailed grammatical specifications followed by a sentence that they determine in a fairly versatile fragment of English. Various methods of description are available, the least satisfactory one being the 'NP + VP' variety. Another does the same for formulae in predicate calculus. Another gives the student a sequence of writing (commonly called 're-writing') commands, suited to the specification of a particular sentence. It then pauses while the student obeys the commands. When the student is ready the correct result is printed out and the student can appraise his performance. This program and the one on quotation, etc., provide the means of automatic examination and marking in these topics where correct technique is of the essence.

There is a program dealing with various forms, choosable by a user, of alphabetic-shift ciphers. Work with this promotes awareness of the incoherence of such forms of talk as 'encoding one's thoughts', unhappily so prevalent in today's literature. Finally, in the current version, a program asks for an English verb, asks 'past or present?', 'finished or continuing?', etc., then prints out the so specified form of the verb, e.g., 'was jumping', 'does not sit', 'will have sung'.

Devising these programs requires, and their running illustrates, a degree of rigour that is sadly lacking even in the most pretentious current treatments of language, cognition and artificial intelligence. The system, developed on a rather antiquated DEC PDP8 (24K bytes plus disc), is written in a, by modern standards, primitive version of BASIC. It should therefore be directly, or with only slight modification, transferrable to any modern microcomputer having a disc. Calls on files are so numerous, in certain items, that a non-disc system would be intolerably slow for CAI, though it would still eventually provide proper printouts.

A PATHWAY TO COMPUTER ASSISTED LEARNING

Gloria Robbins

INTRODUCTION

Experience in establishing a system of computer assisted learning (CAL) in the School of Medicine at Flinders University provided the author with a clear indication that this form of educational technology can extend students' opportunities for learning and increase their motivation.

Factors which now make CAL an economic possibility with academic potential in higher education include:

- the much lower cost and improved dependability of microcomputers;
- availability of relatively straightforward programming languages, including some developed specially for use with CAL;
- a greater awareness of the need to cater for differences in background knowledge and interests of students;
- an acceptance by course designers of the need to achieve greater flexibility through splitting courses into more manageable learning modules;
- the need for a system of instruction which allows regular monitoring of students' progress and of the effectiveness of the teaching materials.

A curriculum in the 1980s tends to be less structured and more geared to self-directed or self-generated learning than one designed in earlier years. A policy of diversity of teaching methods allows scope for the introduction of Computer Assisted Learning (CAL) techniques, which use the computer to aid and enrich the learning process (Harding, 1980). The term 'Computer Assisted Instruction' (CAI) is commonly used to encompass the various teaching modes such as tutorials, problem solving exercises, multiple-choice questions, or simulations; while 'Computer Managed Instruction' (CMI) has an emphasis on monitoring student progress, recording data for subsequent evaluation, and providing a facility for booking tutorials and guiding students to further instructional material. CAL, being the more general term, may comprise one or both of CAI and CMI.

The advent of microcomputers to the educational field has ended the situation where a department wishing to initiate a CAL project has to depend on a busy central mainframe computer system or else find money for an independent microcomputer. There are occasions, however, when resources allow a much more versatile combination of mainframe, mini and microcomputers. In a situation such as this, the microcomputers can function as independent computer systems or as terminals to the two larger systems.

An example of the development of a very satisfactory system of Computer Assisted Learning using a combination of the three levels of computer systems may be found in the School of Medicine, Flinders

University, where a decision was made in 1976 to incorporate some CAI material into the medical curriculum. Funds were accordingly set aside for upgrading the main university computer system. It was subsequently found that, because CAI made heavy demands on resources in the mainframe computer, it was necessary to purchase a minicomputer, which was dedicated to CAI, the main computer being used as a backup system and for data storage. The cost at that point for the upgrade of the main computer, the purchase of the minicomputer with five associated display terminals, random access slide projectors and cassette recorders was approximately $168,000, of which half was spent on the upgrade (Chalmers *et al.*, 1980). In 1980 the first of a number of microcomputers was bought. These increased access to the system and at the same time provided even greater versatility. They are portable (on trolleys) and can be moved to a seminar room or laboratory, be located in a department, or even be taken outside the university for demonstrations of the library of CAI material. Each microcomputer cost approximately $3300 and consists of a display screen and keyboard, processor, 48k bytes of memory and a floppy disk drive.

The capability of using colour as well as graphic illustrations and animation on a microcomputer screen leads to creative presentation of material, and it is pleasing to note that authors of CAI programs are making use of these features, especially in the scientific field. As with the larger systems, a random access projector can be connected to the microcomputer, adding immensely to the value of the textual material (Robbins *et al.*, 1980). An example of such usage is appended to this paper.

Whether microcomputers or larger computers are used for CAL, the success of the technique relies heavily on the quality of the computer programs (software) and their relevance to the curriculum. CAL programs may be purchased or exchanged, but care needs to be taken to ensure that they will run on the receiver's machine with little or no modification of either the text or the machine code. It is likely that assistance from a person with programming skills will be required to enable these programs to be used. If an instructor decides to prepare his own CAL programs, he will have a choice of using a high level programming language like BASIC or PASCAL, or of using a CAL author language such as PILOT or DECAL.

The language BASIC can be easily learned with the help of a textbook, a friend and access to a computer, while it is probably better to attend a short course in PASCAL before attempting to use it for CAL. A combination of BASIC and PILOT allows a much more powerful CAI program to be prepared. One such combination, called BPILOT, has been written specifically for use with the TRS 80 microcomputer, but versions are being developed for use on other machines such as the Apple and the Pet. At least one of our colleagues at the ANU is enjoying the challenge of developing CAI programs on the relatively inexpensive Dick Smith system 80 microcomputer, which plugs into one's home TV set. For a few hundred dollars one can have personal CAI system, but to implement CAL with large classes the cost is naturally greater.

PILOT (Programmed Inquiry, Learning or Teaching) is a programming system for controlling interactive conversation. A PILOT program consists of a series of statements which give a description of what the computer must do in order to interact with a person sitting at a computer terminal. An instruction code, consisting of one or two letters, defines the statement type. A person unfamiliar with a programming language can begin writing a PILOT program using only four statements: T for 'type'; A for 'accept'; M for 'match'; and E for 'end'.

```
T:  Are you overweight?
A:
M:  NO, NOT
TY: Good for you!
TN: You should perhaps diet and take some exercise!
E:
```

The first statement (T) causes the terminal to display the text following the colon. The A statement tells the terminal to expect some action on the keyboard. The M statement causes a scan of the character(s) that has (have) been typed in. If either NO or NOT is found, the message 'Good for you!' will be displayed, otherwise the remark following TN: will appear. An E statement ends a program. The advantage of an author language like this is that natural language can be used by the person at the terminal, whereas in languages such as BASIC it is more usual to have the student choose a numbered option for an answer. Nevertheless, as typing skills are not found in many students it is usually better to keep to numerical or single letter answers! An advantage of BPILOT, compared with the normal PILOT program, is that if the letters MS: are used at the beginning of a matching statement, the computer will accept a student's answer in which two letters are reversed (a common typing error) or where one letter is incorrect. Another valuable feature of the BPILOT program is that it checks the correctness of numerical answers within limits defined by the programmer.

The effective operation of the CAI unit at Flinders is not only a result of the configuration of computers, projectors and tape-recorders with a suitable programming system; it depends very much on the staffing policy adopted, in which a close working relationship is established between the technical staff of the CAI unit and the academic staff of the medical faculty. Together they work as a team on the design and implementation of CAI programs for teaching medicine. The CAI unit is headed by an Instructional Designer (CAI) who combines computer programming skills with a sound knowledge of the principles of programmed instruction. Other technical staff include a Computer Operator, who is also responsible for supervising the two CAI laboratories, and two Clerical Assistants who perform the necessary data processing. The medical staff, therefore, do not have to spend time on programming their material, but are responsible for the design of the textual material and any supplementary audio-visual material.

The Respiratory Physiology course for second year students at Flinders provides a good example of how the system operates. It is based on eight tape-slide programs and workbooks prepared by Dr John West of the University of California (San Diego). A series of eight matching computer programs of a tutorial nature were designed at Flinders to assist students to understand this subject, one of the few qualitative subject areas in the medical course. As Flinders accepts a small percentage of medical students without a science and mathematical background, the subject had been a hard one for students. It is entirely up to the student whether or not the computer programs are attempted; however, if a student asks the lecturer in charge of the course for help, he or she is told to try working through the programs. Within the programs, if a student fails repeatedly to grasp a point, a message comes up on the screen suggesting that the student, through the computer, make an appointment for tutorial help. This help is then given on a one-to-one basis. One example from these programs is included in the appendix.

Good use of Computer Managed Instruction (CMI) is also demonstrated in the Respiratory Physiology programs. The subject matter being quantitative, the computer supplies each student with a unique set of figures to work with so that no 'correct answer' sheet may be compiled. A student can leave the program he is running at the end of a question and may carry on at the next question when he returns. As well as keeping student records, all answers are stored for evaluation purposes and some simple item analysis is done.

It is now fairly common practice for courses at upper secondary and tertiary levels, whether taught by CAI or by more traditional methods, to be split into a series of more manageable modules, which are not necessarily taught in a fixed sequence. Where resources are available, CMI may be used for keeping student records and comparing their performance on the different modules, thus alerting teaching staff to the need for course modifications in modules where the majority of students are having difficulties. At the same time, CMI may be adopted for those modules which lend themselves most to this form of instruction or for providing supplementary material in other modules.

There is a wide range in age, motivation, and background experience in any group of students today. To cater for the learning needs of such a group, each of its members has to be considered individually, for it is no longer appropriate to run a standard course. CAL offers a means of diagnosing a student's strengths and weaknesses and then offering challenging material on the one hand and remedial material on the other. This is accomplished by branching to relevant programs automatically after receiving information typed in by the student at the terminal. It is a medium where students can work equally well as individuals or in small groups at a terminal. It is an experience to observe two or three students working through well-presented material, both in the high degree of involvement between them and the problem presented, and in the interpersonal discussion.

A new dimension to learning is being added with the development of microcomputer systems associated with colour, sound, graphics, and animation. We simply have to be prepared to experiment with ideas for their use, either on their own or in conjunction with the facilities offered by a larger system.

REFERENCES

J.P. Chalmers, G.E. Robbins and G.J. Fraenkel. The Flinders curriculum: Flinders University of South Australia. Supplement on Medical Education, *Medical Journal of Australia*, 1980.

R.D. Harding. Computer assisted learning in higher education. *Studies in Higher Education*, 1980, 5 (1), 101-114.

G.E. Robbins, J.P. Chalmers and D. Higgs. A three-dimensional computerised patient management problem: an example of a computer system utilising written text, sound track and visual projection. *Medical Journal of Australia*, 1980, 1, 362-364.

EXAMPLE 1: Use of Visual Material in a CPMP about a patient with rapid atrial fibrillation and Bacterial endocarditis.

What would you like to do now?

33. Chest x-ray.
34. Blood cultures.
35. ECG.
36. Echocardiogram.
37. Perfusion ~~lung~~ scan.

?33

33. You should start with an ECG before sending the patient away to have a chest x-ray. However, when the chest x-ray was done 1 hour later, the following film was obtained -

Look at slide 6, this shows:

38. Enlarged left atrium indicating mitral stenosis.
39. An enlarged heart with pulmonary plethora.
40. Slight cardiac enlargement with pulmonary venous congestion.
41. Left ventricular enlargement.
42. Large heart with pericardial effusion.

?38

38. The left atrium is enlarged, but the heart is generally enlarged too, and not typical of pure mitral stenosis. Look at this x-ray on slide 7, showing mitral stenosis with an enlarged left atrium.

?40

40. Correct. The heart is generally enlarged and the upper lobe vessels are particularly prominent.

EXAMPLE 2:

What do you think this ECG shows? (slide 54)

1. Left ventricular strain pattern.
2. Old anterior infarct.
3. Ischaemic SW-T wave changes.

?2

No, have a look at this ECG which shows Q waves in the anterior chest leads. (slide 57)

Type 1 for tutorial

Type 1 for tutorial - you feel you need human intervention.

Type 2 tutorial not required - you'll read up on your own.

TIMETABLE

1. Mon. 11.00 2.* 3. Mon. 11.30 4*

Slots with * have been taken.

Type number of slot you require: 3

Michael will see you Monday, 11.30 in the CAI Laboratory.

COMPUTER AIDS FOR TEACHING DRAWING AND RECOGNITION OF NON-ROMAN CHARACTERS TO TERTIARY STUDENTS

Iain Macleod

The ANU's Department of Engineering Physics and the Woden School in Deakin (which caters for mildly intellectually handicapped students in the primary and secondary age ranges) have been collaborating since 1974 on a study of computer-based techniques for assessing and developing basic skills with such students (Macleod and Overheu, 1977). Much of this work has been concerned with teaching of beginning handwriting and reading skills to preliterate students. The emphasis has been on developing new educational strategies, rather than on adapting existing methods for computer presentation.

What then is the relevance of this work to teaching intellectually able students at institutes of higher education? In a sense, tertiary students who are commencing study of foreign languages which use non-Roman characters and/or scripts also are preliterate. There are good reasons for believing that the techniques developed at the Woden School could, with appropriate modifications, form valuable adjuncts in teaching tertiary students to draw and recognise such characters. The problem of learning a new set of characters is most difficult in the case of languages such as Chinese (with approximately 10,000 ideographic characters in common use) and Japanese (with approximately 2,000 Kanji characters plus two syllabaries).

Handwriting (i.e., drawing the characters used in a written language) has been taught for upwards of four thousand years but methods of teaching, largely by copying or tracing of given finished samples, have remained fairly constant. The system of computer-based handwriting instruction developed at the Woden School has significant advantages compared to traditional methods, primarily as a result of the computer's ability to monitor performance and control information presented during handwriting exercises (Macleod and Lally, 1981; Lally, 1980).

The system developed (Macleod and Procter, 1979) uses a PDP-11/20 computer to control a DIGIVUE display screen—a 21.7 cm square matrix of 512 by 512 neon-orange light points which can be lit or extinguished individually. A digitiser pen is used in conjunction with the display. Its position is calculated from the lengths of two lightly-tensioned fine strings which pass through eyelets at the left and right above the display and which are attached to the pen tip. A switch inside the pen indicates its up/down status and the impression of writing is created by drawing a lighted track under the tip of the pen as it is pressed down and moved around the screen. A small square cursor box drawn on the display continuously indicates the calculated pen position and avoids problems with parallax errors.

Handwriting exercises are presented as a series of strokes (straight or curved), each of which has to be tracked before the next stroke is drawn. Successful tracking requires the student to start off with the cursor box enclosing the beginning of a thin (1 point wide) guide line presented for each stroke and to move along the guide line (within an accuracy defined by the cursor box size) with the pen down. As students track the thin guide line successfully it changes into a thicker path (3 points wide). If the student starts at the wrong end of a stroke, moves in the wrong direction, lifts the pen or moves too far off the guide line, path filling stops and a small blinking spot (5 points square) calls the student's attention back to the point where the pen should be. The required accuracy of tracking is varied by changing the cursor box size. The visual pattern which develops on the screen is the model being tracked, rather than actual pen movements used, thus avoiding visual reinforcement of a student's possibly ill-formed initial attempts.

As students become more adept at drawing the characters being practised, the guide lines can be made invisible. The blinking spot gives a cue as to the starting position of each successive stroke but not as to its shape or direction. The system can be used for general graphic characters and pictures. In one of the exercises used at the Woden School for introducing the system and as a reward for good performance, 'secret' pictures of cars, cartoon characters, rockets, etc. are used. These are constructed from sequences of strokes in the same way as characters, but with the order of strokes chosen such that the object being drawn does not become clear until most of the strokes have been completed. The present system could thus be used for practice of Chinese and Japanese characters, but it does not take account of the varying stroke thickness sometimes employed with these characters. To allow practice with variable thickness strokes, a modified pen is being constructed which will give a continuous reading of pen pressure rather than simply 'pen up'/'pen down'. Different thickness lines will be drawn on the graphic display under the pen tip according to the pen pressure on the display surface.

Other techniques developed at the Woden School which are relevant to the current application include those employed for teaching of sight words (Lally, 1981) and of sound/symbol associations (using both individual letters and letter groups). In one exercise, the symbols or words to be recognised are drawn on a translucent overlay with large buttons underneath. Digitised speech is used to give directions to students. A student might be asked to press on a given symbol or word, for example. Learning is enhanced through appropriate feedback on performance and repeated presentations of symbols which are not recognised correctly. A new device constructed in the Department of Engineering Physics consists of a graphic display screen (256 by 256 resolution) with a pressure activated digitiser panel in front of the display. This device will be much more flexible than the current 'button box' because it will be possible to draw rapidly any subset (of, say, 16 characters) being learned, to ask the student to press on one or other of the characters displayed and to register which character was selected. This type of approach will allow exercises which are better suited to the intellectual abilities of tertiary students than would an overlay of say 16 characters in fixed positions. High quality digitised speech used in conjunction with such exercises would also help students to improve their punctuation.

Discussions with the ANU's Department of Chinese have identified several potential benefits of computer-aided learning in this area. There is a large number of characters to be learnt and practice at synthesising patterns tends to have a positive effect on ability to recognise those same patterns. The computer-aided methods for teaching sound/symbol associations would complement drawing exercises and offer an interesting alternative to existing methods. Systems developed at the Woden School are being adapted for the purpose of teaching ANU students to draw and recognise Chinese characters, with the objective of conducting limited trials during the 1981 academic year.

REFERENCES

M.R. Lally. Computer assisted handwriting instruction for retarded school children (1980, in submission).

M.R. Lally. Computer assisted teaching of sight word recognition to retarded children. *American Journal of Mental Deficiency*, 1981, 85 (4), 383-388.

I.D.G. Macleod and M.R. Lally. The effectiveness of computer controlled feedback in handwriting instruction. Proceedings of the 3rd World Conference on Computers in Education (1981, in press).

I.D.G. Macleod and D.L. Overheu. Computer aided assessment and development of basic skills. *The Exceptional Child*, 1977, 24 (1), 18-35.

I.D.G. Macleod and P.S. Procter. A dynamic approach to teaching handwriting skills. *Visible Language*, 1979, 13 (1), 29-42.

CAL IN THE TEACHING OF STATISTICS

Hugh Mahon

According to Mr Mahon, students entering tertiary education today are on the one hand more sophisticated in their lack of fear of computers, but on the other hand insufficiently grounded in basic mathematics, even for the relatively simple statistics which they must use in many of the natural and social sciences. There are, for example, many concepts which are counter-intuitive and may therefore be proved only by mathematical methods.

For some students a mathematical proof fails to get the concept across; for these people the only way in the past was to carry out a large number of observations, such as recording the results of tossing two coins repetitively. Microcomputers can simulate a large number of events or observations and quickly give frequency distributions.

Mr Mahon commences his course by asking his students to carry out some physical measurement or observation twenty to thirty times, and then to repeat the operation using a microprocessor. A microprocessor can also be used to demonstrate what happens to a distribution when the parameters are varied. Mr Mahon uses this facility regularly.

CAI IN THE TEACHING OF ENGINEERING

D. Magin

Mr Magin described how the Tertiary Education Research Centre (TERC) at the University of New South Wales has responded to requests from lecturers in the School of Engineering for assistance with course design. Teachers of Engineering were seeking a method of simulating conditions encountered by engineers in the field, a problem which readily lends itself to solution by computers, yet would be almost impossible using other methods.

Reasons given by Mr Magin for using CAI included the efficiency of the process, its effectiveness in improving learning, its ability to extend laboratory experiences, and the opportunity it provides for filling gaps in the curriculum.

Mr Magin also pointed out that computers have the advantage of being able to provide instant data production, thus enabling students to concentrate on other aspects of experimentation.

COMPUTERS AND ARTIFICIAL INTELLIGENCE

Michael Cook

In this paper Dr Cook described the development of CAL as a substitute for teachers and books. He reminded the audience that programmed texts preceded computers and listed some of the features of this form of teaching.

Dr Cook also addressed the questions of how one might replace a teacher with a computer and what particular advantages computer-assisted learning may have over the older programmed texts. The difficulty with these, he claimed, was that they tended to follow a standard format. There was an implicit assumption that all questions have answers that require quite simple choices, or that answers may be either right or wrong. In addition, any training effected by programmed texts tended to be strictly linear. To a certain extent this limitation also applies to CAL, according to Dr Cook. At least a book allows some ideosyncratic scanning either forward or backward.

Dr Cook also pointed out that although most methods of programmed learning cater for a range of levels of treatment, CAL allows more sophisticated options to be offered. An additional problem is that whereas in 'normal' education a teacher can make allowances for partial learning, this is very difficult to do with programmed instruction.

Dr Cook asked whether this is the type of knowledge structure we really want. He concluded by stating that if we are seeking computers with an expert knowledge of the subject to be taught, it will be necessary to develop much more complex computers.

ARTIFICIAL INTELLIGENCE AND CAL

Robin Stanton

Dr Stanton discussed the problems associated with the encoding of knowledge in a computer program and reminded the audience that while some disciplines lend themselves to this type of coding, others do not. Machines which are much more intelligent than current ones are needed before they are able to use normal language and demonstrate the qualities of an expert in the subject.

He asked what type of program would be needed for real CAL. This is a particularly important question when there are many legitimate ways of tackling the same problem. Dr Stanton also referred to the difficulty of representing a range of the various meanings associated with a particular word.

CLOSING REMARKS

John F. Ogilvie

Traditionally the function of a university has been taken to be, in concise terms, to generate and to transmit knowledge. Whilst we relate generation of knowledge to research, we can analogously associate transmission of knowledge with teaching, although both teaching and research constitute the learning process.

Nobody can doubt the tremendous effect of electronic digital computers on the practice of research, first in the physical sciences and mathematics by means of arithmetic conducted with a speed and endurance far surpassing, for a single major machine of recent design, the total arithmetical capacity of all human beings who have ever lived. During the past decade the impact of these computers and their miniature counterparts alike has been felt across all the breadth of disciplines of a modern university, such that a department of English, for instance, has sought to revive enrolment by honours students (and incidentally to enhance the vocational skills of its graduands) by devising projects in literary analysis involving use of computers. The capability of computers for such tasks depends on the processing and storage of information in much more than an apparently numerical manner.

We can compare the storage capacity of various devices in the table below. The figures demonstrate that a human brain has potentially a capacity that is vast by comparison with the other means of storing information. Yet many experienced teachers may have difficulty in reconciling the notional capacity of their students with the content of even a single textbook.

Table 1. COMPARISON OF CAPACITY, IN TERMS OF MILLIONS OF (ALPHABETIC OR NUMERICAL) CHARACTERS, OF VARIOUS MEANS OF STORING INFORMATION

DEVICE	CAPACITY
typical book	1.3
floppy disk (computer accessory)	2.5
large (fixed) disk (computer accessory	313.
optical disk (under development)	12 500 000.
largest encyclopaedia	12 500 000.
largest magnetic cartridge (computer accessory)	250 000 000.
national archives (USA)	12 500 000 000.
human brain	125 000 000 000.

Assuming that university students inherently possess this effectively infinite capacity to absorb knowledge, then one has to admit that a major problem of educational effectiveness arises in the process of transmission and assimilation of knowledge. Actually mere absorption of information is not a proper educational objective. Any academic discipline, whether in 'pure' or 'applied' subjects, has the intent for the student not only to acquire knowledge, by commitment to memory, but also to learn both methods of analysis and skills characteristic of that discipline. Traditional pedagogical methods at the university level have included the 'stand-and-deliver' lecture, self-study or reading designated texts, and the tutorial or dialogue approach, in addition to practical classes, in different combinations depending on the philosophy of the discipline and the surrounding society at a particular time and place. We cannot be certain that these traditional methods are the most effective for all students (the collection of individual persons) in all disciplines. On the contrary, we have continual proof of the fallibility of these methods in every set of examination results.

The alternative methods more recently developed, involving teaching machines, programmed-learning texts, use of audio-visual aids and computer-assisted instruction, undoubtedly have, and will have proved, a legitimate role in the teaching process, in some cases supplementing, in others supplanting, aspects of traditional methods. As academic practitioners we have the duty to become aware of, to investigate these innovations for teaching, and to apply them appropriately. The computer has incontrovertibly insinuated its influence into the research and administrative components of the activities of academic staff; the teaching component cannot remain isolated from such a restive power.

There has been the fear that such technological discoveries will permit a large-scale replacement of academic staff by machines. Because our students, retaining human qualities and properties, will continue to need the human guidance and inspiration that no machine can impart, these fears lack foundation. The most drastic changes that one can envisage are the re-alignment of boundaries between traditional subject areas, the incumbent revision of approaches to teaching the re-organised bodies of knowledge, and the re-formulation of methods of use of the knowledge. Yet these aspects are but one facet of the progress of our civilisation, not to be opposed but rather to be embraced, as the technological revolution affects educational practice as much as any other activities of mankind.

Our symposium on bringing computers into college and university teaching has served the purpose of creating or intensifying an awareness in the participants (and in the readers of these proceedings) of how the computer is ~~being~~ currently used by some of our innovative colleagues, in a great diversity of disciplines, to improve not only the skills of their students and the breadth of their learning experience but also their recognition of the computer as a vital force within our dynamic society.

BIBLIOGRAPHY

GENERAL

J. Annett. *Computer assisted learning: 1969-1975.* London: Social Science Research Council, 1976.

J. Annett. *Report on a research seminar on computers in education, 14-16 July 1976.* Coventry: Psychology Department, University of Warwick, 1976.

P.B. Ayscough. CAL — boon or burden? *Chemistry in Britain*, 1976, 12, 348-352.

Carole Bagley. CAI update: so you want to do CAI? *NSPI Journal*, 1979, 18 (2), 35-36.

Alfred Bork and Stephen Franklin. Personal computers in learning. *Educational Technology*, 1979, 19 (10), 7-12.

George R. Brubaker. CAI: two strategies. *Creative Computing*, 1979, 5 (10), 130-134.

E. Edmonds. Where next in computer aided learning? *British Journal of Educational Technology*, 1980, 11, 97-104.

J. Fielden and P.K. Pearson. *The cost of learning with computers.* London: Centre for Educational Technology, 1978.

J.R. Hartley. An appraisal of computer-assisted learning in the United Kingdom. *Programmed Learning and Educational Technology*, 1978, 15, 136-151.

Emanuel G. Hertzler. Audible computer-assisted instruction: toward the complete CAI. *Educational Technology*, 1979, 19 (9), 45-47.

R. Hooper. *National development programme in computer-assisted learning: final report of the Director.* London: Centre for Educational Technology, 1977.

R. Hooper et al. *Computer assisted learning in higher education: the next ten years.* London: Centre for Educational Technology, 1977.

J.A.M. Howe. Artificial intelligence and computer assisted learning: ten years on. *Programmed Learning and Educational Technology*, 1978, 15, 114-125.

J.F. Huntingdon. Microcomputers and university teaching. *Improving College and University Teaching*, 1980, 28 (2), 75-77.

Chak Chi Lau. The ABC's of CAI. *NSPI Journal*, 1979, 18 (5), 24-25.

Bebe F. Lavin. Can computer-assisted instruction make a difference? An analysis of who benefits. *Teaching Sociology*, 1980, 7 (2), 163-179.

Gyorgy Lazar. Trends of education in computer techniques. *Computers and Education*, 1979, 3 (2), 127-133.

B. Macdonald et al. *Understanding computer assisted learning*. Norwich: Centre for Applied Research in Education, University of East Anglia, 1978.

H.F. McMahon. Progress and prospects in computer-managed learning in the United Kingdom. *Programmed Learning and Educational Technology*, 1978, 15, 104-113.

Carol L. Miller. Authoring for computer-based training. *NSPI Journal*, 1979, 18 (9), 13-17.

John Moore et al. Computer series 5: computer-aided instruction with microcomputers: Part 1, systems and applications. *Journal of Chemical Education*, 1979, 56 (12), 776-783.

R.J. Osborne and C.J. Potter. Self-evaluation tests using interactive computer terminals. *Assessment in Higher Education*, 1979, 4 (3), 171-179.

J.F. Rockart and M. Morton. *Computers and the learning process in higher education*. New York: McGraw-Hill, 1975.

D.A. Smith. A study of computer-assisted instruction in a university environment. *Chemistry in Australia*, 1977, 44, 265-267.

S.G. Smith and B.A. Sherwood. Educational uses of the Plato computer system. *Science*, 192, 344-352.

C. Douglas Spitler. Rules for authoring computer-assisted instruction programs. *Educational Technology*, 1979, 19 (11), 13-20.

Symposium: computer assisted learning. *British Journal of Educational Technology*, 1977, 8 (3).

D.A. Tawney (ed.). *Learning through computers*. London: Macmillan, 1979.

D.A. Tawney. New light in old corners: reflections prompted by observing some computer assisted learning developments. *Journal of Higher Education*, 1977, 2, 69-77.

San-Yun W. Tsai. Student achievement in computer programming: lecture *vs* computer-aided instruction. *Journal of Experimental Education*, 1978, 46 (2), 66-70.

A.J. Wearing et al. *Computers and teaching in Australia*. Canberra: Australian Government Publishing Service, 1976.

L. Zinn. An overview of current developments in computer-assisted learning in the United States. *Programmed Learning and Educational Technology*, 1978, 15, 126-135.

BIOLOGICAL AND OTHER SCIENCES

G. Beech (ed.). *Computer assisted learning in science education.* Oxford: Pergamon, 1978.

Allan Crease. Developing CAL for undergraduate science teaching. *Physics Education*, 1977, 12 (1), 48-51.

K. Garbutt *et al.* A CAL-based undergraduate genetics course. *Computers and Education*, 1979, 3 (4), 353-359.

J.R. Hartley. Computer assisted learning in the sciences: some progress and some prospects. *Studies in Science Education*, 1976, 3, 69-96.

Richard Hooper. Computers in science teaching ... an introduction. *Computers and Education*, 1978, 2 (1-2), 1-7.

S. Katz *et al.* Computer simulation in the physiology student lab. *Physiologist*, 1978, 21 (6), 41-44.

J. McKenzie. Computers in the teaching of undergraduate science. *British Journal of Educational Technology*, 1977, 8, 214-224.

J. McKenzie *et al.* (eds). *Interactive computer graphics in science education.* Chichester: Horwood, 1978.

James W. Small and Kathryn Edwards. Simulating drosophila genetics with the computer. *American Biology Teacher*, 1979, 41 (4), 219-225.

I.C.H. Smith. The Pet 2001 and CAL: its use in the physiology laboratory. *Computers and Education*, 1979, 3 (4), 361-365.

Ruth von Blum. Mastering genetics with a little help from GENIE. *American Biology Teacher*, 1977, 38 (8), 468-472.

CHEMISTRY

P.B. Ayscough. Application of computer-assisted learning methods in the teaching of chemical spectroscopy. *Computers and Education*, 1979, 3 (2), 81-92.

Ellen Bardole and Jay Bardole. Two-year community college chemistry: joules. *Journal of Chemical Education*, 1978, 55 (5), 323-324.

J. Barrett, A.E. Breezer and A.W. Ellis. Computer assisted graphical displays. *Education in Chemistry*, 1976, 13, 17.

J. Barrett and A.E. Breezer. Experiments with computer assisted graphical displays. *Education in Chemistry*, 1977, 14, 42.

R.G. Baughman. Hydrogen-like atomic orbitals—an undergraduate exercise. *Journal of Chemical Education*, 1978, 55, 315.

M. Ben-Zion and Z. Goldschmidt. Simulated NMR spectroscopy and shift reagents. *Journal of Chemical Education*, 1977, 54, 669.

M. Ben-Zion and S. Hoz. Interactive classroom graphics—simulating non-linear Arrhenius plots. *Education in Chemistry*, 1980, 17, 101.

D.G. Berge and M.L. Vander Wielen. Computer program for solving a spectrophotometric three component mixture. *Journal of Chemical Education*, 1979, 56, 396.

M. Bishop. Computer assisted instruction in qualitative analysis. *Journal of Chemical Education*, 1977, 54, 689.

M. Bishop and M. Nowak. Computer assisted instruction in stereochemical configuration analysis. *Journal of Chemical Education*, 1979, 56, 318.

D. Bond. Computer simulation in organic chemistry—thin layer chromatography. *Journal of Chemical Education*, 1978, 55, 323.

G.L. Brenneman. More CAI programs. *Journal of Chemical Education*, 1979, 56 (12), 783.

G.L. Brenneman. X-ray fluorescence simulation. *Journal of Chemical Education*, 1979, 56, 303.

G.L. Brenneman. Infrared spectra simulation. *Journal of Chemical Education*, 1979, 56, 340.

R.D. Burkhart and P.N. Howells. Collecting and manipulating digital data in an experiment on electronic spectroscopy. *Journal of Chemical Education*, 1979, 56, 249.

K.G. Calkins and R.F. Daley. Computer assisted analysis of nuclear magnetic resonance spectra. *Journal of Chemical Education*, 1978, 55, 322.

D.J. Carswell and A.E. Mihkelson. The microcomputer in CAL applications. *Education in Chemistry*, 1980, 17, 37.

Claudia S. Cavin. Effects of computer simulated or laboratory experiments and student aptitude on achievement and time in a college general chemistry laboratory course. *Journal of Research in Science Teaching*, 1978, 15 (6), 455-463.

C.S. Cavin, E.D. Cavin and J.J. Lagowski. A study of the efficacy of computer-simulated laboratory experiments. *Journal of Educational Chemistry*, 1978, 55, 602.

R. Chabay and S.G. Smith. The use of computer-based chemistry lessons. *Journal of Chemical Education*, 1977, 54, 745.

J.P. Chester and M.A. McGinn. Simulating chemical reactions. *Education in Chemistry*, 1979, 16 (5), 154.

P.J. Cox. Computer aided assessment. *Education in Chemistry*, 1979, 16, 18.

T.A. Ford. Determination of the vibrational constants of some diatomic molecules. *Journal of Chemical Education*, 1979, 56, 57.

S.Z. Goldberg. EQUBAL—a computer program for balancing chemical equations. *Journal of Chemical Education*, 1978, 55, 532.

S.Z. Goldberg. Two computer programs for the simulation of X-ray diffraction phenomena. *Journal of Chemical Education*, 1979, 56, 227.

M. Henner, P. Levoir and B. Ancian. An NMR spectrometer—computer interface experiment. *Journal of Chemical Education*, 1979, 56, 684.

H.B. Herman and J.A. Dilts. Computer enhancements of general chemistry and quantitative analysis laboratories. *Journal of Chemical Education*, 1980, 57, 654.

D. Hinds, D.D. Parrish and M.A. Wartell. Modelling of molecular velocity distributions. *Journal of Chemical Education*, 1978, 55, 670.

H. Huber. Simulation of the Old Nassau reaction. *Journal of Chemical Education*, 1979, 56, 320.

M. Liebel. Electron behaviour in a chemical bond. *Byte*, 1980, 5 (3), 34.

D.R. Martingez, A. Bahta, A.H. Black and G.A. Parker. Computer calculations in the quantitative analysis course. *Journal of Chemical Education*, 1979, 56, 309.

R.S. Matthews. Hydrocarbon molecule constructor. *Byte*, 1980, 5 (3), 156.

T. McGrath, M. Kroeger and H. Dunn. Computerized visual aids in introductory MO theory. *Journal of Chemical Education*, 1978, 55, 160.

A.C. Norris. The design of CAL packages for teaching numerical methods to chemistry students. *Computers and Education*, 1979, 3 (4), 347-352.

G.F. Pollnov. Binary liquid—vapour boiling point diagrams on a graphic desk top computer. *Journal of Chemical Education*, 1978, 55, 318.

D.E. Powers, W.C. Harris and V.F. Kalasinsky. Laboratory automation in the undergraduate curriculum. *Journal of Chemical Education*, 1979, 56, 128.

W.G. Rhodes, R. Smock and L. Brown. Ever-more sophisticated lies about bonding. *Journal of Chemical Education*, 1977, 54, 687.

S.G. Smith and R. Chabay. Computer games in chemistry. *Journal of Chemical Education*, 1977, 54, 688.

R.N. Stabler and J.P. Chesick. A computer simulation of stratospheric photochemistry. *Journal of Chemical Education*, 1978, 55, 504.

Jerrol Windbigler. Individualizing chemistry with a computer. *Science Teacher*, 1978, 45 (1), 24-25.

ECONOMICS

J.N. Robinson. The theory and practice of economics: can a computer help to link the two? *Programmed Learning and Educational Technology*, 1977, 14 (3), 207-212.

EDUCATION

Eunice N. Askov *et al.* Application of computer technology in undergraduate teacher education. *English Education*, 1978, 9 (2), 102-109.

Vincent N. Lunetta. Human transactions and classroom management: a computer-based unit in teacher education. *Educational Technology*, 1977, 17 (4), 35-37.

GEOGRAPHY

Allan Collins *et al.* Effectiveness of an interactive map display in tutoring geography. *Journal of Educational Psychology*, 1978, 70 (1), 1-7.

GEOLOGY

Michael J. Frost. Two computer programs for teaching indigenous petrology. *Journal of Geological Education*, 1977, 25 (5), 148-149.

LANGUAGE

Robert Ariew. A diagnostic test for students entering a computer-assisted learning curriculum in French. *Computers and Education*, 1979, 3 (4), 331-333.

Michael Clutterbuck. The computer in foreign language teaching. *Babel*, 1979, 15 (1), 33-37.

Henry W. Decker. Computer aided instruction in French syntax. *Modern Language Journal*, 1976, 60 (5-6), 263-267.

Richard T. Scanlan. A CAI course in vocabulary building through Latin and Greek roots. *Foreign Language Annals*, 1976, 9 (6), 579-583.

Richard T. Scanlan. Computer-assisted instruction in French. *Foreign Language Annals*, 1980, 13 (1), 53-55.

Robert M. Terry. Students work with MONIQUE and learn French. *Foreign Language Annals*, 1977, 10 (2), 191-197.

LAW

Harry G. Henn. Computer assisted law instruction: clinical education's bionic sibling. *Journal of Legal Education*, 1977, 28 (4), 423-426.

LAW (contd.)

Kenneth A. Zick. Developing and implementing a law school WESTLAW orientation program. *Law Library Journal*, 1975, 72 (2), 260-275.

MATHS

D.W. Daly *et al.* The computer-assisted learning project in mathematics at the University of Glasgow. *International Journal of Mathematical Education in Science and Technology*, 1977, 8 (2), 145-156.

Andrew D. McGettrick. Mathematics by computer-assisted learning—the real problems. *International Journal of Mathematical Education in Science and Technology*, 1979, 10 (1), 65-73.

Howard Peelle. Teaching mathematics via APL. *Mathematics Teacher*, 1979, 72 (2), 97-116.

PHYSICS

John Dowd. An interactive computer experiment for the introductory laboratory. *American Journal of Physics*, 1978, 46 (1), 63-64.

M.K. Summers. Physics CAL with microcomputers. *Physics Education*, 1979, 14 (1), 7-14.

SOCIOLOGY

George H. Conklin. Using the computer in introducing sociology: a solution to the 'methodology problem'. *Teaching Sociology*, 1976, 4 (1), 83-95.

Vivian Klaff. Population education through computer generated graphics. *Journal of Educational Technology Systems*, 1976, 4 (4), 245-269.

STATISTICS

Craig L. Gjerde. Integration of computers into a course on biostatistics. *Journal of Medical Education*, 1977, 52 (8), 687-688.

Richard H. Williams. On the teaching of order statistics and supporting conversational computer programs at the pre-college level. *Contemporary Education*, 1977, 48 (2), 66-72.