Appraisal of Computer Aided Instruction at the Open University and the evaluation of three specific programs.

Thesis

Appraisal of Computer Aided Instruction at the Open University and the evaluation of three specific programs.

A dissertation submitted to the Open University in part fulfilment of the requirement for the degree of Bachelor of Philosophy in the field of Computer Aided Instruction in Physics.

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Abstract

This dissertation begins with a review of different types of Computer Aided Instruction. A classification scheme developed from a variety of similar systems found in the literature is used to analyse the different forms of Computer Aided Instruction (CAI) in use at the Open University. The analysis is considered to be particularly relevant in view of the fact that some 10,000 student-terminal hours were devoted to CAI programs at the Open University during 1976.

The main type of CAI program in use at the Open University is the computation type. However, in the Physics discipline of the Science Faculty, which is the author's particular concern, the type of CAI program in use is of the calculational experiment type. Hence three calculational experiment programs used at the Open University's Summer School by the Physics discipline were selected for further scrutiny.

A study was undertaken to determine the effect of each program on student learning. No significant gains were noted. However, the use of relatively small groups

(because of existing constraints) and tests which could have been more reliable may have contributed to this. The effect of each program on student attitudes was also measured, and it is of interest to note that with larger student groups, and more reliable measures, each program had a significant, and positive, effect on student attitudes towards the use of the programs concerned.

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CHAPTER 1

A Review of Different Types of CAI Usage.

In this chapter I give examples of the various uses of computers in instruction. This serves the double purpose of clarifying the meaning of the classes and of setting a background of existing work against which the OU applications can be seen. I have not attempted to list or describe all the numerous CAI projects which exist or have existed.

In drawing up a classification system for OU computer programs I have distinguished four major uses in educational establishments:

- Research,
- Administration,
- Teaching of computing,
- Aiding instruction.

I am only concerned with the fourth use, that is, the use of computers as an aid to instruction, an area loosely defined as Computer Aided Instruction (CAI) or Computer Assisted Learning (CAL).

In order to be able to describe and give examples of different types of CAI/CAL a classification scheme is necessary. Classification schemes have been developed by, among others, Hooper (1975), Hickey (1969), Taylor, Edwards, Norton, Van Dusseldorp and Weiss (1974), Feldhusen and Szabo (1969) and Rockart and Scott Morton (1975).

The scheme I have used has its roots in the classification schemes already mentioned, but it is tailored to suit the situation at the Open University. The scheme is as follows:

- Tutorial and Remedial Tutorial
  - Linear
  - Intrinsic
  - Adaptive
- Dialogue
- Simulation
- Calculational Experiment
- Computation
- Learner-Controlled
  - Data Base

Own Route

Project

Computer Managed Instruction

To clarify this classification scheme each of the categories, or modes of use, is described below with examples to illustrate the mode.

1.1 Tutorial

In the tutorial mode the computer functions as a tutor, presenting students with either new, or remedial materials. Three subcategories of the mode may be considered, namely linear, intrinsic and adaptive.

1.1.1 Linear

The linear mode is often called the drill and practice mode. All the students follow the same pattern of questions and answers. The only individualisation allowed is in the rate of completion.

Most of the examples of this type of instruction are in the areas of elementary arithmetic or reading. However it has been used in college chemistry courses to help students who enter with inadequate high school science, or mathematics, backgrounds (See Johnson (1973)).

At Stanford, Suppes and Morningstar (1970) developed a drill and practice system for arithmetic. According to them the program was designed to drill and review students on concepts previously presented in the classroom by the teacher. The drill and practice system used in 1967, was for grades one to six (American grades). The drill material for each group was arranged into twenty-five sequential 'concept blocks'. Each block consisted of a pretest, five days worth of drill, a post-test, review drills and review post-tests. In a seven day period a student went through each of these components.

For each day of review or drill there were five levels of difficulty. A student was placed at a particular level depending initially upon his pre-test performance and subsequently upon his previous day's performance. Thus the individualisation obtained was dependent upon an off-line overnight assessment of the students' achievements. According to Suppes (1971), this system has since been modified so that the focus of attention is the individual child, rather than the class to which he belongs. Hence the underlying questions have changed from 'What grade is this child in?' and 'What is usually taught at that grade level?' to 'What concepts has this child mastered?' and 'What should this child learn next?'

1.1.2 Intrinsic

In both the intrinsic and adaptive modes students follow different patterns of questions and answers. In the intrinsic mode each question is determined by the student's immediately preceeding response.

Atkinson (1969) provides us with an example of the intrinsic mode in describing the project at Stanford to teach initial reading.

The terminals for this system consisted of a picture projector, a cathode ray tube, a light pen, a modified typewriter keyboard and an audio system to play pre-recorded messages.

When a student incorrectly responded to a question from the computer, the computer branched to a remedial section determined by the type of error made by the student. If the student made errors in all the sections of the questions, then all the sections of the remedial work were used and a message was sent to the tutor. The actual system used was more complex than I have indicated here since more than one strategy was used for the teaching of reading.

In a study of the effectiveness of the computer work Atkinson divided the students (children) into two groups. One group received reading instruction from the computer and the other group, which functioned as a control group, received reading instruction from a teacher. The children in the control group were provided with mathematics instruction from the computer. This was done because the students in the experimental group might otherwise have done better just because they were the centre of attraction. The two groups were not significantly different at the start of the experiment, but the post-test scores for the group receiving reading instruction from the computer were significantly better (except for one sub-test) than the group receiving conventional instruction in reading.

1.1.3 Adaptive

In the adaptive mode each question is determined by a series of responses which typically may be responses to attitude, personality and/or achievement.

Hansen, Kribs, Johnson and Dick (1973) at Florida State University have studied in depth several aspects of the use of computers in instruction. They define the adaptive mode as follows: 'adaptive instruction attempts to match an individual's unique characteristics with optimum treatment dimensions.' In other words the computer makes use of the student's responses to determine what should next be presented to him.

They initially investigated the learning and personality variables which might be useful in predicting and assigning remedial instruction, lesson length and other instructional variables. In the first model of the adaptive mode the predictor variables consisted primarily of performance variables. Later on personality variables were added in a phased approach to determine which predictors resulted in outstanding performance levels.

1.2 Dialogue

The dialogue mode goes beyond the tutorial mode in allowing the student to ask for an answer, solution or data, at any point in the interaction. In its most advanced theoretical form it would allow the student to converse with the computer in a natural language. This does not appear to have been achieved yet, but steps have been made along this path.

The dialogue mode is the one which is least developed. The main difficulty has been in developing a computer system which will allow the student to respond in a natural language without restriction on the form of the response. Various efforts have been made to achieve this aim by developing systems which can break down a student's input into its component words, checking these words against a key-word list. The computer output is a restructured sentence mainly composed of the key words.

Taylor (1968) provides us with an example of such a program in describing ELIZA. The program has two parts, a key-word list and a set of rules. The word list contains the key words for the particular problem being operated on. There is a set of decomposition rules to break down the input sentence, and a set of reassembly rules to form the output from the computer. Taylor has used ELIZA in college level physics.

Ellis (1974) describes another system which falls into this category. In this case the computer is used to assist in careers guidance for school pupils.

Holland and Hawkins (1972 p.367) describe a dialogue system at Harvard which is used to teach techniques of medical diagnosis. In a sample dialogue the student assumes the role of an admitting physician in a hospital. The student's task is to make a diagnosis, and to prescribe treatment for a 'patient' with a specified background displaying a set of symptoms. The student has available a vocabulary of questions and statements he can pose to the computer. He can also request laboratory tests and various pieces of data (e.g. blood pressure).

Munch (1972) describes a program written at the University of California at Irvine. This program, concerned with coupled oscillations in physics, allows the students free-form input.

Brown, Burton and Bell (1974) describe a more advanced form of dialogue use. Their system, named SOPHIE, can be classified as dialogue, though its authors call it 'Artificial Intelligence'. SOPHIE can respond on its own to a student's questions, evaluate the student's hypotheses, and provide detailed feedback about the student's answers. SOPHIE was used specifically for electronic troubleshooting. Brown *et al*. give the following reasons for this. Electronic troubleshooting represents a qualitative commonsense kind of reasoning that has never been satisfactorily studied. Typical troubleshooting laboratories have severe limitations because the number and type of faults is limited by practical considerations. However using SOPHIE they were able to develop especially powerful inference procedures.

The system is considered to be more powerful than key word analysis.

1.3 Simulation

In the simulation mode the computer is used to simulate a particular experience, condition, or behaviour.

It has been used in a variety of contexts to simulate conditions that students cannot experience in student life. Some of the areas in which it has been used are: economics, space-craft training, laboratory experiments and statistics. Hansen, Kribs, Johnson and Dick (1973) have studied simulation and say 'much of the debate in this area continues to be over the potential for simulation to affect attitudinal and/or cognitive growth'. They see one of the primary advantages of simulation to be the reduction in costs due to the reduction in expensive laboratory experiments. A second advantage of simulation is the ability to do 'experiments' without danger. In their investigation into simulated laboratory experiments they showed that it was as efficient as traditional laboratory methods when evaluated by post-test performance and total instructional time.

Lagowski (1970), provides us with examples of three different types of simulated experiment at the University of Texas.

The first type is the decision making experiment in which students first gain an understanding of the techniques involved from a session in the laboratory. They then use the computer to gain experience in applying the technique. Thus the student has opportunity to make decisions about chemical analysis as he uses the computer.

The second type is that in which complex equipment would be used if the experiment was done in the teaching laboratory. Emission spectroscopy, X-ray diffraction experiments and Rutherford scattering provide us with appropriate examples of such experiments.

The third type is the time compression, or time expansion, type of experiment such as kinetics experiments which require periodic sampling over periods from ten to twenty four hours. In such simulated experiments the student makes decisions about the experimental parameters, collects the data from the computer, and determines one of the kinetically important parameters of the system.

Evaluation has not been conducted on these simulated experiments because students cannot normally undertake the real experiments, thus making comparisons difficult.

1.4 Calculational Experiment

The calculational experiment mode of program is similar to the simulation mode. The calculational experiment programs are often involved with fundamental laws (which may be quite complex, e.g. Schrödinger's Equation) in very simplified environments. An example in Quantum Physics is the solution of the 'particle in a box' problem. Simulation programs on the other hand often deal with fairly simple laws in a complex environment. An example is the flow of ships in the English Channel where the navigation law is fairly straightforward, but the number of ships involved makes the problem quite complicated.

1.5 Computation

In the computation mode students solve problems with the help of the computer which can be thought of as a large calculator. In some cases students write their own programs, in other cases the programs are provided by the tutors. Often the problems are of the type which involves reduction of experimental data.

Harding (1975) provides us with an example of students writing programs to solve their own problems when he describes the CATAM project, which was developed for applied mathematics students.

The use of the BASIC programming language at Dartmouth College is the outstanding example of an easy to use computer facility, and is described by Holland and Hawkins (1972 p.379). Any student on the campus can use the computer for his own purpose and many do.

Other examples of programs provided for students are described in Dowling (1972) and Ehrlich (1973). Some of these programs will analyse student data by means of statistical measures, such as chi-square tests and least squares fit to straight lines, saving students from long and tedious calculations.

1.6 Learner-Controlled

The learner-controlled mode has three sub-categories, namely data base, own route and project.

1.6.1 Data Base

In the data base mode the student has access to a data base and a suite of programs to enable him to manipulate the data.

Meyers (1969) describes such a usage at Dartmouth College where the subject of the data base is social science. The large amount of stored data can be retrieved and manipulated, to ascertain trends and to check hypotheses, by a suite of programs.

The system is designed to be used by faculty members for research purposes and by undergraduates to gain experience of data analysis.

The facilities available can be split into three sections: a standard teaching package, a standard research package and an open-ended section.

The teaching package consists of a library of programs designed to lead the student through the process of data analysis. The programs ask the students questions, such as whether they want tables percentaged horizontally, vertically or not at all. In responding students have the opportunity to make bad decisions. However, the beginning student is limited to a few routines to enable him to become familiar with the data analysis involved.

The programs in the research package provide more of the available methodologies than the teaching package. It goes without saying that questions are not included in the research package.

The open-ended section is to provide experienced researchers with the opportunity to devise their own data analysis programs.

1.6.2 Own Route

In the own route mode students choose their own paths through the instructional material. They are presented with a set of topics within a given subject and choose which topic they wish to study in the order, and at the level, they prefer.

This mode has been exploited in a course on statistics by Grubb (1969). Its main advantage over other forms of tutorial usage is that it recognises individual differences between student needs. In other forms of tutorial usage most students proceed down a main trunk with only a few detours on the way.

For a course in statistics, for example, there will be many reasons why students will take the course. Some will want to browse through the course as a first insight into various techniques or as a means of reinforcing previous knowledge. Others may only want to understand a limited number of statistical methods without devoting the time required to go through the whole course.

In each of these cases the aims of the students are quite different, and suggest very different approaches to the subject. In addition there are many reasons why a student responds to a question, or questions, in the way he does. 'Computer Controlled Programs' have to predict the causes of erroneous action. This is based on subjective judgement which inevitably cannot be 100% correct. Learner-control permits a student to predict his own needs.

The course is arranged in a series of charts. The first chart which any student sees is a block diagram of the course. The student can then choose any of the blocks. Within each block there will be other smaller blocks which the student can choose. This process is repeated until the student reaches a teaching package about one particular part of statistics. The student can backtrack from any of the blocks if he gets into difficulty.

1.6.3 Project

This type of program has mainly been used with children. In project based use of the computer the projects extend over several days or even weeks. The goal for children is to obtain a work style, in other subjects, similar to that in the better art classes. The child becomes more involved with his work because the project allows him to try out some of his ideas. According to Papert (1972) 'the technology is used not in the form of machines for processing children but as something the child himself will learn to manipulate, to extend, to apply to projects, thereby gaining a greater and more articulate mastery of the world, a sense of power of applied knowledge and a self-confidently realistic image of himself as an intellectual agent.'

The use of the language LOGO is the prime example of this style of teaching. It gives children unprecedented power to invent and carry out exciting projects by providing them with access to computers with peripheral devices capable of producing on-line real-time action, and is particularly easy to use. For instance, LOGO can drive motors, switches mechanical devices and activate electromagnets. Mathematics is the subject which has been most taught by LOGO, but some problems in mechanics can be taught using it. It also has list manipulative capabilities which children have used to write concrete poetry.

1.7 Computer managed instruction (CMI)

In the computer managed instruction mode students are directed to learning packages on the basis of a knowledge of their objectives and their achievements on tests. The learning packages may be computer based, but may well be more conventional packages such as lectures, self-teaching materials or laboratory experiments. After completing the package the student is tested and directed to another package.

(The testing of students using a computer is sometimes included in this category, but I regard this as administration, which is outside the scope of my classification.)

This mode of computer usage has been studied by Hansen _et al_. (1973) who point out that at the inception of their project (ONR Themis) in 1967 researchers were concerned with 'the computer as the teacher'. At the end of five years of research they believed that the concept of computer based training is broader than originally conceived, and profits best from a management model for instruction.

They devised a CMI system which consisted of the following:

diagnostic assessment and the assignment of individualised learning prescriptions,

the use of computer work for practice and remedial purposes,

the use of simulation for role and decision making training purposes,

the use of the computer for ease and objectivity of curriculum development, and a record system so that the individualised training process could be effectively monitored and managed.

1.8 Discussion

There has been some concern about the use of computers to individualise instruction. Ellis (1974) suggests that they legitimise current practice instead of looking for better ways to teach. This appears to be a well-founded concern since some users have used the computer as a page turning device, and - as Silberman (1969) indicates - a very expensive one at that!

There is also some discussion about cost. There are several different cost estimates, but it is difficult to compare them since they are not all based on the same assumptions. In making estimates however, one must generally ask how are the costs of the computer work determined, how many students can use the computer and how many hours per day is the computer available to students? Economics of computerised instruction are discussed at length by Kopstein and Siedel (1969).

In deciding how much per student hour a system costs one of the difficulties is in deciding how to budget the costs of writing the program. If the program is written by a faculty member how is it costed? Is the cost of the software spread over all the users? Budget estimates are particularly difficult when the computer is a central facility shared among administration, research and instructional uses.

In estimating costs one must consider whether the program can be transferred between different institutions. If the program can be run on many different computers the cost of writing it can be spread over a larger student body. Some attempt has been made to write programs in FORTRAN or BASIC which, according to Lata and Crain (1973), appear to be more easily transferred than programs written in authoring languages such as COURSEWRITER. Nevertheless, as Hooper (1975) indicates, there are difficulties in using programs at institutions other than the authoring one, because the amount of knowledge possessed by the students, and the order in which it is taught, will be different at different institutions.

The cost of tutorial mode programs also depends on whether the program is remedial or not. If it is remedial then the author does not have to supply as much printout as when it is a straight teaching program.

Jamison, Suppes and Wells (1974) suggest that at elementary school level CAI is apparently effective as a supplement to regular instruction. They also say that at secondary school and college levels CAI is about as effective as traditional instruction when used as a replacement. However, supporting evidence appears to be limited. Nevertheless Hansen et al. (1973) reported that interim investigations of CAI have indicated that it is useful in a number of technical training areas, and that it has proved especially useful for dynamic graphics such as found in engineering dynamics.

In conclusion it is worth pointing to the advantage of the tutorial mode in that it facilitates educational research in the field by storing student responses, which can then be evaluated. Thus, as Seidel and Kopstein (1969) indicate, it is often possible to use the computer to conduct experiments outside the closed confines of the laboratory using a variety of instructional strategies.

CHAPTER 2

Types of CAI in use at the Open University

This chapter reviews the different types of CAI programs in use at the Open University (OU) and provides some indication of the extent to which such programs are used.

2.1 Use of different modes of CAI at the Open University

Table 1 provides a breakdown of programs in use at the OU at the end of 1976, indicating the type of program and the faculty in which each program was used. The types of program are discussed below in terms of the classification system described in Chapter 1. As shown in the table, the computation mode accounts for about 60% of the programs, while the simulation mode accounts for 20%. The actual breakdown of programs according to their mode of usage is discussed in the following subsections.

2.1.1. Tutorial

2.1.1.1. Linear

The linear mode has been used primarily in the Mathematics and Technology faculties (see appendix 1) mainly to give help to students in areas, such as trigonometry, in which they may need practice.

Table 1: Number of programs in each mode by faculty up to the end of 1976

Mode / Faculty	Tutorial			Simulation	Calculational Experiment	Computation	Learner-Controlled	Total	%
	Linear	Intrinsic	Adaptive						
Arts	0	0	0	0	0	0	0	0	0
Social Sciences	1	0	0	0	2	17	0	20	15.7
Educ. Studies	0	0	0	1	0	9[2]	0	10	7.9
Maths.	6	2	0	8[1]	0	37	0	53	41.7
Science	0	0	3	5	6	8	0	22	17.3
Tech-nology	3	0	0	11[1]	0	7	1	22	17.3
Total	10	2	3	25	8	78	1	127[3]	~100
%	7.9	1.6	2.4	19.7	6.3	61.4	0.8		

1 One program, MATCH, is used in both M100 and T100, and it follows that the number of different simulation programs used by the Mathematics and Technology Faculties is 18 rather than 19.

2 All 9 programs used in Educational Studies courses are also used in Social Sciences courses, and it follows that the number of different computation programs used by the Educational Studies and Social Sciences Faculties is 17 rather than 26.

3 Of the 127 programs used by the different Faculties 10 are used in two different Faculties. It follows that the number of different programs in use is therefore 117, and not 127.

2.1.1.2 Intrinsic

The intrinsic mode has been used in two programs (M201U7 and M201RT described in appendix 1) in the same Maths. course (M201). Both the programs expect the student to know something about the subject matter before they are used.

2.1.1.3 Adaptive

The adaptive mode has been used in the Science Faculty (courses S100 and ST294) using programs borrowed from the CALCHEM[4] project.

The new course TM281 Modelling by Mathematics has three programs in the tutorial mode.

Use of the tutorial mode must be handled with care, because as one progresses from linear to adaptive the time taken in writing the programs increases substantially, hence caution must be exercised in the use of the

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[4]CALCHEM: Computer Assisted Learning in Chemistry is an inter university project funded by the National Development Programme for Computer Assisted Learning. The CALCHEM staff at Leeds University and Sheffield Polytechnic have cooperated with staff at the OU. on these programs.

tutorial mode. In this respect it is of interest to note that the easier to program linear mode is used by 10 programs (described in appendix 1) in the OU to help with basic skills and knowledge, the more difficult to program intrinsic mode is used in only two programs (M201U7 and M201RT), while the adaptive mode programs, which are the most difficult to write, have been borrowed from outside bodies, and are limited to these programs (Acids and Bases, Bond Energies and Enthalpy Changes and Planning an Experiment).

2.1.2 Dialogue

This mode has not been used at the OU up to now.

2.1.3 Simulation

It has already been noted that 20% of the programs used in the OU for aiding instruction are in the simulation mode with 75% of these being used in the Technology and Mathematics faculties. (See appendix 1 for a list of all the programs). Six out of eleven simulation programs in Technology (MANSIM, SIMSTR etc.) are concerned with simulating systems, while five out of eight of those in Mathematics (MATCH, TEASER etc.) are games designed to familiarise students with the computer terminal and computer usage. One program (GDRIFT) in the Science faculty is concerned with the simulation of experiments. This appears to be a particular relevant function of CAI in the OU because it permits the simulation of experiments which could not be performed either at home or at Summer School. (Even though the Science faculty uses only one simulation program to simulate experiments it uses 3 calculational experiment programs (RUTHER, PATHS and ENGIN) for much the same purpose.)

The new course TM281 has three programs in the simulation mode.

2.1.4 Calculational Experiment

Calculational experiment type programs account for 6% of all the programs (as shown in table 1) compared with 20% identified as simulation type.

One of the major areas of use of calculational experiment programs is Physics (PATHS,ENGIN etc.) where they are often used to help the student identify characteristics of theoretical models. It is possible for calculational experiment programs to be used for simulation purposes and in such circumstances care is required in categorisation

2.1.5 Computation

As already mentioned the computation mode is the most popular type of program in use at the OU. The Mathematics faculty uses the largest number of these programs (54%). Computation programs used at the OU vary from those in which the students write their own programs (Programming Option, T100) to those which are provided to help students analyse data (HIST, D301).

2.1.6 Learner-Controlled

2.1.6.1 Data Base

There is one program of this type in use in the Technology faculty (course T341). The program, called IDA, was developed at Chicago University. As the OU is a large organisation perhaps it should produce this type of program.

2.1.6.2 Own Route

There are no programs of this type at present at the OU. However such programs might be useful in second and third level courses which have student populations covering two or more faculties. In such cases student requirements often vary considerably, and such programs could well be used to enable students to reach the same level of knowledge by a variety of routes according to students' specific needs.

2.1.6.3 Project

There are no programs of this type at present in use at the OU. However, the course D303, cognitive psychology, which is due to be offered in 1978, plans to use a programming language which has its roots in LOGO, although it differs structurally from the latter.

Using this language students will be expected to learn about computers while undertaking interesting activities.

2.1.7. Computer Managed Instruction

It seems that the Open University is in an ideal situation for CMI programs since it conducts its teaching in packages, has Computer Marked Assignments and has a wide spread of terminals through the Student Computing Service (SCS). In particular the analysis of CMAs could be used to manage the teaching of individual students. No such usage had been recorded in the OU up to the end of 1976.

However, the new course ST291 Images and Information, (introduced in 1977) uses a limited form of CMI in which students are provided with remedial tutorials by the computer. The remedial tutorials are of the adaptive type with back up from a human tutor who can speak to the students over the same telephone line that connects the terminal to the computer. The student inputs answers to a set of questions provided in correspondence material. From the profile of responses the computer takes the student through a remedial tutorial which may well direct him back to related sections of the text.

A further limited use of CMI is worth noting in course E201, where a new program (CICERO) was introduced in 1977 to provide students with feedback on CMA type questions.

2.2 Analysis of CAI usage during 1976 in terms of Student - Terminal hours and Postal usage

The breakdown of CAI usage by mode only tells a part of the story of computer usage. It does not indicate the number of students involved or the time students spend in using such packages. The time students spend using CAI programs is reviewed in the following sections in terms of student-terminal hours, and postal jobs (see below) according to the course involved rather than the program concerned.[5]

2.2.1 Breakdown of CAI usage by Course

Students using CAI programs may submit responses to the SCS computers either directly by using a local terminal or indirectly by sending responses by post to the SCS Walton Hall computer. The latter course of action may be preferred where students do not live near a terminal or where for a variety of reasons (such as the quantity or complexity of data involved) they prefer SCS to enter the data into the computer. It therefore follows that CAI usage may be measured in terms of the

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5 A breakdown according to specific programs, and specific modes, was not possible from the SCS data available.

number of hours students spend at terminals and the number of jobs they submit by post. Needless to say the measures are independent and cannot be equated to one another.

CAI programs[6] account for 30% of student usage of SCS terminals (measured in student-terminal hours) and 26% of postal service jobs submitted to SCS. The degree of CAI usage varies from course to course, and this is recorded in tables 2 and 3.

It is of interest to note that 40.1% of student-terminal hours for CAI programs are devoted to courses in Technology and a further 14.0% to courses containing a Technology element. 52.9% of student-terminal hours for CAI purposes may similarly be attributed to the Foundation Courses in Technology, Mathematics and Science.

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6. The programs referred to are listed in appendix 1. It should be noted that whether or not a computer program is described as CAI may be a matter of some debate. Estimates of the degree to which CAI is used in the Open University may therefore be subject to some variation.

In contrast Technology and Foundation Courses respectively only account for 6.9% and 11.1% of CAI jobs submitted through the postal service. By far the greatest user of the postal service is the Social Sciences Faculty which alone accounts for 49.1% of CAI postal jobs submitted, and in joint courses accounts for a further 12.7%. It is of interest to note those courses (D222, E201, MST281, S100, S299, ST294, ST285, SM351) which make no use whatsoever of the postal service, even though they do have computer components.

Table 2: Student-terminal hours for CAI courses in 1976.

Course	Student-terminal hours	As % of total CAI usage
D222	15	0.1
D281	275	2.7
D291	45	0.4
D301	55	0.5
D305	279	2.7
E201	370	3.6
E341	271	2.7
M100[7]	1468	14.4
M201	821	8.1
M321	17	0.2
MDT241	584	5.7
MST281[8]	30	0.3
MST282	52	0.5
S100	919	9.0
S299	122	1.2
ST294	315	3.1
ST285 }	447	4.4
SM351 }		
T100[9]	3000	29.5
T241 }	1075	10.6
T341 }		
TOTAL CAI	10160	
Other uses	23686	
	33846	

[7]Course used for both CAI and other computing purposes. Terminal hours used by CAI is based on estimate of 15% of total use as supplied by member of SCS.

[8]Course used for both CAI and other computing purposes. Terminal hours used by CAI is based on data supplied by SCS about tutorial use.

[9]Course used for both CAI and other computing purposes. Terminal hours used by CAI is based on estimate supplied by member of course team.

Table 3: Postal Service usage for CAI courses in 1976.

Course	No. of jobs processed by P.S.	As % of total CAI
D222	0	0
D281	6	0.9
D291	10	1.5
D301	40	6.0
D305	272	40.7
E201	0	0
E341	136	20.3
M100[10]	68	10.2
M201	2	0.3
M321	1	0.1
MDT241	85	12.7
MST281[10]	0	0
MST282	3	0.4
S100	0	0
S299	0	0
ST294	0	0
ST285 } SM351 }	0	0
T100[10]	6	0.9
T241 } T341 }	40	6.0
TOTAL CAI	669	
Other uses	1898	
	2567	

[10]Courses used for both CAI and other computing purposes. Figures for the number of jobs processed by the Postal Service are based on estimates of the CAI use in each course provided by members of SCS and course teams (see note under Table 2 for further details).

2.2.2 Breakdown of CAI usage between Summer Schools and Home Study Centres

CAI programs are in fact used in two quite different situations at the Open University. On the one hand they are used by students in the normal course of events while studying at home. In such situations students may choose to submit their responses to the SCS either by means of terminals at local study centres or by means of the postal service. On the other hand CAI programs are also used at Summer Schools. In such situations terminals and supervisors are available at the location, and there is no need for the alternative postal service which is therefore limited to use by home based students.

The actual breakdown of CAI usage between Summer Schools and Study Centres for each course is indicated in Table 4. From this it is clear that of the eight courses which make no back up use of the postal service only two courses (ST294, ST285) limit their CAI activities to Summer School, and one must ask why the other six make no use of the postal service to back up the terminal use. Finally, it is of interest to note that 49.6 % of CAI terminal usage is in fact at Summer School.

Table 4: Student-terminal hours at Study Centres and Summer Schools for CAI courses in 1976.

Faculty	Course	Student-terminal hours	
		Study Centre	Summer School
Social Sciences	D222	15	0
	D281	9	266
	D291	45	0
	D301	55	0
	D305	279	0
Educational Studies	E201	370	0
	E341	271	0
Mathematics	M100[11]	734	734
	M201	116	705
	M321	17	0
	MDT241	584	0
	MST281	10	20
	MST282	52	0
Science	S100	373	546
	S299	45	77
	ST294	0	315
	ST285	0 }	429
	SM351	18 }	
Technology	T100	1500	1500
	T241	218 }	
	T341	413 }	444

[11]It has not been possible to obtain estimates for the split between Study Centres and Summer School for these courses. Hence 50% of the total CAI usage has been entered under Study Centre and 50% under Summer School.

CHAPTER 3

A Brief Description of Three Calculational Experiment Programs selected for Evaluation at Summer School.

The three programs selected for evaluation were WELLS, PBAR and MAXB. All these programs are of the calculational experiment type of program. WELLS and PBAR were used at the 'Quantum theory and atomic structure' (SM351) Summer School and MAXB was used at the 'Solids, liquids and gases' (ST285) Summer School.

3.1 What the programs do

3.1.1 WELLS

WELLS uses an ordinary teletype as a terminal. Using this program the student can find the eigenvalues and eigenfunctions of bound states of a square well and harmonic oscillator well by taking an initial estimate of an eigenvalue for a particular potential well and then determining whether the function fits the boundary conditions imposed by the continuity of the wave function. At the Summer School students first made an estimate by a coarse integration step using hand calculators. They then proceeded to check, refine and extend their first attempt by using the computer.

Using the program they were able to check their first estimate of the eigenvalue, and by successive approximations they were able to refine their first estimate and find the correct value of an eigenvalue for that potential well. The students were able to extend their first attempt by proceeding to find further eigenvalues for that well. They were also able to change the size of the well, find the eigenvalues for it, specify one other type of well and determine the eigenvalues for it.

Using the computer program to make integrations for an harmonic oscillator well was a valuable link to the MEASUR program which occured later in the week. In the latter program measurements of a quantum harmonic oscillator were simulated.

3.1.2 PBAR

PBAR uses a graphical visual display terminal as the link between computer and student. The program uses the terminal to display what occurs (in terms of waves) when a particle is incident upon either a potential barrier or a potential well. The parameters which can be altered are the height or depth of the barrier or well, the width of the barrier or well, the mass of the incoming particle and the energy of the particle.

The student can choose from four displays the one he wants to view at any one time. The four displays are: the real part of the wavefunction, the imaginary part of the wavefunction, both real and imaginary parts of the wavefunction and the probability density. The student may also use the program to calculate the transmission coefficient for a wave passing through the barrier or well.

At the Summer School the program was mainly used to enable students to find how the transmission coefficient varied as the particle energy was altered for a fixed potential, and permitted students to investigate the shape of the wavefunction by altering the parameters.

3.1.3 MAXB

MAXB uses a teletype for a terminal. The program simulates a model of a gas which the students have previously seen. The rules of the model are the same as the rules for Maxwell-Boltzmann statistics. The input data for the program are the number of particles in the model (maximum number is 10) and the total energy to be shared amongst them (maximum 12 units). The program is limited to the maximum values shown because if the students were allowed to input any larger values for the parameters it would take the computer a long time to produce the results. The program calculates all the different types of macrostates which can occur with the given input data and all the microstates for each macrostate. The students can choose between having information about each macrostate and the total distribution or just information about the total distribution.

At the Summer School students were provided with a set of questions which could be answered by using the program. The main aim of the latter was to familiarise the students with the model, and to enable them to obtain a better understanding of how the model behaves. This is particularly important when calculations involved more particles than students could manage with hand calculations. The program also gives the students an idea of the shape of the Maxwell-Boltzmann distribution and helps to clear up how the microstates and macrostates are arranged.

3.2 THE RÔLE OF THE PROGRAMS IN THE COURSES

3.2.1 Quantum theory and atomic structure

Program WELLS involves material in course units 5, 6, 7 and 8 especially units 7 and 8. The students study these units just before the Summer School, when Television programme 5 is shown. This programme relates to the same material as WELLS. The material in PBAR is similar to that shown in Television programme 4.

There are not very many applications of Quantum Theory in the course. Hence it is useful to emphasise the applications shown in WELLS and PBAR. The program serves to reinforce the analytical solutions of Schrödinger's equation, thus providing help on related questions which are always found in Tutor Marked Assignments and the final examination.

The comparison of different solutions in a well brings in other concepts such as ground state energy, parity and binding energy.

3.2.2 Solids, liquids and gases

Maxwell-Boltzmann statistics is an important concept in the course, used in describing chemical activity and diffusion activity in liquids and solids.

The unit which deals with Maxwell-Boltzmann statistics has turned out to be one of the more difficult units in the course. This was one of the reasons why the program was produced. The unit describes three models which simulate a gas: a crude two dimensional model, a better two dimensional model and a three dimensional model. MAXB's model is the same as the three dimensional model which is described in the unit and shown on the Television programme associated with it.

There is always a Tutor Marked Assignment and generally a part of a Computer Marked Assignment on Maxwell-Boltzmann statistics in the assessment of this course.

CHAPTER 4

The Effect of three CAI Programs on Student Learning at Summer School

A study was undertaken at the Physics Summer School during 1976 to evaluate the three CAI programs described in Chapter 3. This chapter describes the nature of the evaluation and determines what effect the programs had on student learning. The effect of the programs on student attitudes is reviewed in Chapter 5.

4.1 Introduction

The two courses involved in the evaluation were SM351 (Quantum Theory and Atomic Structure) and ST285 (Solids, Liquids and Gases). Both of these courses held Summer Schools at the same time in the same place (the University of Sussex). Both courses used several computer programs during the Summer School week. SM351 used two computer programs in addition to WELLS and PBAR; they were MEASUR and RUTHER (loaned from CUSC). ST285 used two additional programs which were PATHS and ENGIN.

The particular reasons why WELLS, PBAR and MAXB were chosen for evaluation were as follows. WELLS was a new program in 1976, it replaced a different program, in the same subject area, used in previous years and it was felt that with the experience of the previous program this program should be showing positive effects. PBAR, as already mentioned, was loaned to the OU. Part of the agreement for the loan was that detailed feedback should be provided. PBAR was chosen instead of RUTHER because it could be evaluated alongside WELLS. MAXB had only been used the previous year and was partially written by the author, thus it was of interest to determine how effective it was.

4.2 Experimental design for all three Programs

There were several factors to be taken into account in the choice of an experimental method. These were that the evaluation had to fit into the overall Summer School timetable and a rigorous method of evaluation for the tests was required. Surveying the various methods available in Campbell and Stanley (1966) the method which best fitted the above factors was the Solomon four group method. This involves two experimental groups and two control groups. One of the experimental groups is pre-tested and one is not, similarly one of the control groups is pre-tested and one is not. Students are allocated at random to the groups, in this case it was done by alphabetically allocating students to groups according to surname.

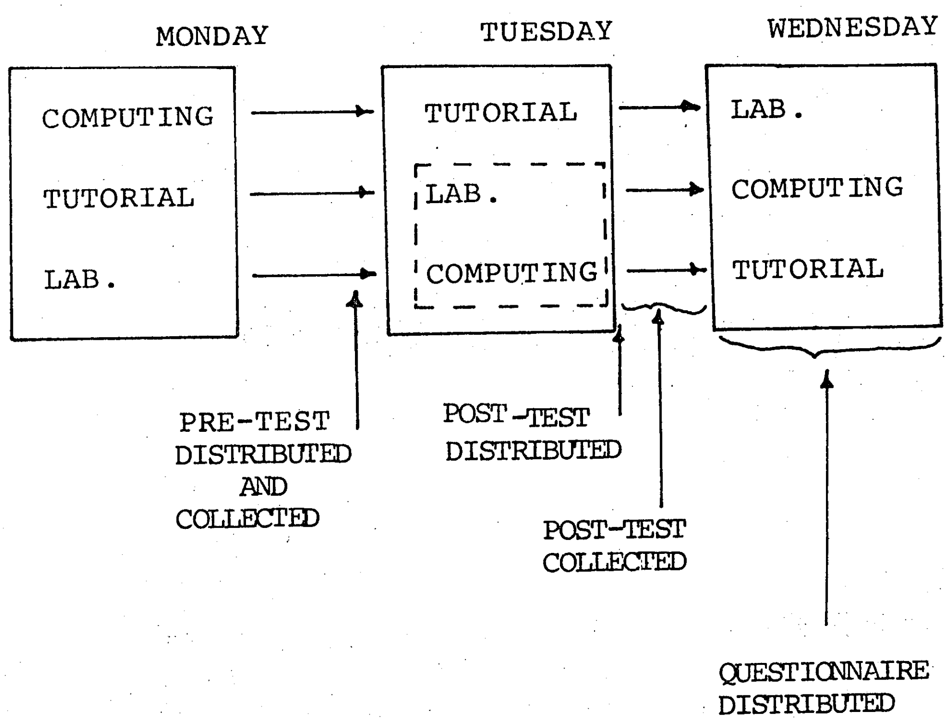
4.2.1. Experimental Design for WELLS and PBAR study

WELLS and PBAR are grouped together in this section because they followed exactly the same procedures.

Only one test paper was used for both the pre-tests and the post-tests.

The Summer School timetable had three groups of students rotating between computing, laboratory experiment and tutorials as shown in Figure 1. The test evaluation only used two of the groups because there was only one time period for computing when there was sufficient spare time before the computing session for the students to do the pre-test. The two groups of students used were those doing computing (of course) and those doing laboratory experiments. Students in these two groups were assigned alphabetically by surname into four sub-groups of approximately equal size. The students in each of these four sub-groups were asked to choose a code number (a cloakroom ticket) from a limited range, no note was made of what number a student had. The students were asked to write

Figure 1 Flow chart for WELLS and PBAR study



their code number on the pre-test, post-test and questionnaire. The code numbers were the only means of identifying the students when they returned their pre-tests, post-tests and questionnaires. This scheme was evolved to assure students of their anonymity because previous experience suggested that students do not like to commit their name to work which is going to be marked even though they are assured that such work is not going to count against their assessment.

The work which the control group of students (those in the laboratory) did during the experiment and the tutorial was unrelated to the content of the tests and computing session.

In the following I call the groups who did the computing, the experimental groups and label them 1 and 2, and I call the groups who were in the laboratory the control groups and label them 3 and 4. Using O to mean an observation (i.e., pre-test or post-test) and X to mean a treatment (i.e. the use of the computer programs) the procedures followed by the four groups can be written as shown in Figure 2.

Figure 2 Experimental procedure for WELLS and PBAR

Group	Procedure	Code Numbers
1 Experimental	O_1 X O_2	1-30
3 Control	O_3 O_4	61-90
2 Experimental	X O_5	31-60
4 Control	O_6	91-120

The number of students who completed the experiment was 57. The students who had to do a pre-test did so in the last fifteen minutes of the previous timetable session. The students returned their pre-tests before the treatment session started. (If any students handed in a pre-test after the session had started, that student was eliminated from the evaluation).

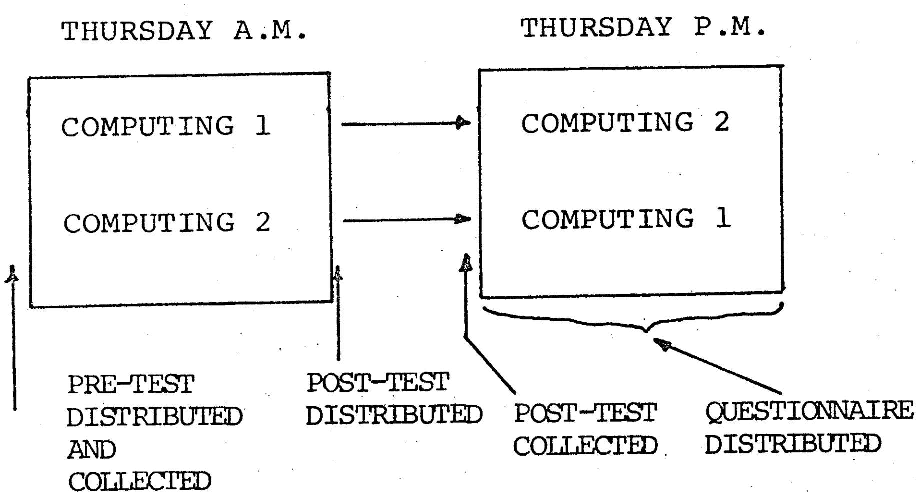
The students then started their session of using the computer or doing laboratory experiments. The two computer programs, WELLS and PBAR, were in use at the same time because they used different computer terminals. When a student or a group of students had finished using their first program they moved to another terminal to use the other program. If the students had any problems while they were using the programs they were given assistance by the tutors.

At the end of the session post-tests, which were the same tests as the pre-tests,were distributed to all the students in the four groups. The students did the post-tests after they had completed the session, and, as with the pre-tests, were asked to complete them on their own without reference to any books.

4.2.2 Experimental Design for MAXB study

The experimental procedure for this program was similar to that used for WELLS and PBAR. Again only one paper was used for both the pre-test and post-test. There were two sessions of computer use scheduled on the timetable. They were both on the same day, the first session in the morning and the second session in the evening, as shown in Figure 3. Computing 1 was concerned with the use of the MAXB program, while Computing 2 was concerned with the use of the PATHS and ENGIN programs. Computing 1 was the independent variable of interest. Computing 2 was a means of providing a control group and the content bore no relationship to the dependent variable (the post-test) which was designed to measure the effect of Computing 1. The students were divided alphabetically into four

Figure 3 <u>Flow chart for MAXB study</u>



groups of approximately equal size and the students in these groups were asked to choose a code number (a cloakroom ticket of a different colour than used for WELLS and PBAR) in a limited range. The procedure followed by the four groups is summarized in Figure 4 where again the symbol O is used to represent an observation (or test) while the symbol X is used to represent the treatment (or independent variable).

The number of students who took part in the experiment was 60. Groups 1 and 2 were designated as the treatment groups, using MAXB. Groups 3 and 4 were designated as the control groups. Students in groups 1 and 3 received, and completed, their pre-test before the first computer session started. After the first session post-tests

Figure 4 Experimental procedure for MAXB

Group	Procedure	Code Numbers
1 Experimental	O_1 X O_2	101-125
3 Control	O_3 O_4	151-175
2 Experimental	X O_5	126-150
4 Control	O_6	176-200

were distributed to all the students who were requested to return the post-tests at the start of the second session. During the first session the students using MAXB were asked to work on their own. (Except for trivial advice, e.g. which key to press.) The students in these groups were told to ask for any help on MAXB after they had returned the post-test. During the second session groups 1 and 2 used PATHS and ENGIN and groups 3 and 4 used MAXB with no evaluation taking place in this session. In 3 cases students spoiled their tests by using code numbers which had already been issued. The results of these three students together with the results of the three students who had already used that code number have been eliminated from the evaluation.

4.3 Dependent variables

Item analysis of the post-tests was used to check the dependent variables. The statistics obtained included the discrimination index for each item, the facility index for each item, the standard deviations of the facility and discrimination indices, the standard error, the error ratio and the internal consistency for each test. The facility and discrimination indices were transformed, as described by Melton (1976), so that the error in each was related only to the number of students responding to each test item.

The criterion used to decide which items were unsatisfactory was the same as that used in the item analysis of S100 1974 CMAs conducted by the Science Education Research Group at the OU. (Described in Melton (1976)). The criterion was that items should be identified as anomalous, or unsatisfactory, if the related transformed discrimination index was less than 30.

The standard deviations are related to the number of students (N) completing the tests by the following formulae.

$$\text{Standard deviation of Facility Index} = \frac{100}{\pi\sqrt{N}}$$

$$\text{Standard deviation of Discrimination Index} = \frac{100}{\sqrt{N}}$$

The standard error provides an estimate of the error associated with each student's score.

The error ratio is simply the standard error divided by the standard deviations of the scores on the test. If the error ratio is high this means that differences between students are largely based on errors in measurement rather than on actual differences in ability.

The internal consistency of the tests is related to the error ratio and is a measure of reliability of the tests. Following Guilford (1965) the total variance in scores on a test can be separated into different components

$$\sigma_t^2 = \sigma_c^2 + \sigma_s^2 + \sigma_e^2 \qquad 1$$

where σ_t^2 is the total variance of a test

σ_c^2 is the variance due to common factors (e.g. intelligence)

σ_s^2 is the variance specific to the test

σ_e^2 is the error variance

Dividing equation 1 by σ_t^2

$$\frac{\sigma_t^2}{\sigma_t^2} = 1 = \frac{\sigma_c^2}{\sigma_t^2} + \frac{\sigma_s^2}{\sigma_t^2} + \frac{\sigma_e^2}{\sigma_t^2} \qquad 2$$

The internal consistency, α can be introduced into equation 2

$$\alpha = 1 - \frac{\sigma_e^2}{\sigma_t^2} = \frac{\sigma_c^2}{\sigma_t^2} + \frac{\sigma_s^2}{\sigma_t^2} \qquad 3$$

Hence eqation 3 shows that the internal consistency is a measure of the variance which can either be related to common factors or is specific to the test.

4.3.1 WELLS and PBAR test

Only one test was used to test both WELLS and PBAR, it contained seven items and is shown in Section A2.1.1, appendix 2. (The test was written by a member of the Physics discipline.)

Of the seven items in the combined WELLS-PBAR test three did not have satisfactory discrimination indices. The internal consistency, the standard error and the error ratio are shown in Section A2.1.2, appendix 2, together with the facility and discrimination indices and the standard deviations of the facility and discrimination indices.

As shown in Section A2.1.2 the internal consistency of the WELLS-PBAR test was 0.08. This means that only 8% of the variance of the scores on the test can either be related to common factors or is specific to the test. Thus 92% of the variance is error variance. This is not a surprise considering that the joint test only contained seven items, three of which were unsatisfactory. Appendix 2 Section A2.1.3 contains a discussion of the items analysis data for this test.

4.3.2 MAXB Test

The test (written by the author with the assistance of a member of the Physics discipline) contained fifteen items shown in Section A2.2.1, appendix 2. Of these items two had poor discrimination indices. Section A2.2.2, appendix 2 shows the facility and discrimination indices and their standard deviations together with the internal consistency, the standard error and the error ratio. As can be seen several items have indices which are within one standard deviation of the criterion for unsatisfactory items.

The internal consistency for the MAXB test was 0.67. That is, 67% of the variance is either related to common factors or is specific to the test and 33% of the variance is error variance.

Appendix 2, Section A2.2.3 contains a discussion about the items in this test with unsatisfactory discrimination indices.

Item analysis thus showed only one of the dependent variables (the MAXB test) to be a satisfactory measure. It was clear that the unsatisfactory test (for WELLS and PBAR) needed to be considerably improved, however, a new test could not be tried out on a similar body of students until the next Summer School, 12 months hence, and it was decided that in the meantime insights might be gained by analysing the existing data, particularly that related to student performance on the MAXB test, and that related to student attitudes towards all the programs.

4.4 Results

The post-test (dependent variable) results were analysed using a 2 x 2 analysis of variance procedure which determined the independent effects on student learning due to both the treatment itself (the use or otherwise of the designated program) and the existence or otherwise of a pre-test. The data was gathered in the form indicated in figure 5.

It was thus possible to determine the significance of the treatment effect (X) from the column means and variances and that of the pre-testing effect from the row means and variances. Any interaction between the pre-testing effect and the treatment could be determined from the cell means and variances.

Figure 5 Format for collecting post-test data (O_2-O_6) for student groups.

	No Treatment Given	Treatment Given
Pre-tested	O_4	O_2
Not pre-tested	O_6	O_5

Three null hypotheses were specified for each program; namely

there is no difference between those groups which received treatment and those groups which did not receive treatment,

there is no difference between those groups which were pre-tested and those groups which were not pre-tested,

there is no interaction between the pre-testing effect and the treatment effect.

Three of the assumptions underlying analysis of variance are described in Popham and Sirotnik (1967). They are; the measures must represent random samples, the variances within the populations from which the subgroups are sampled are homogeneous and the populations are normally distributed. The first assumption is satisfied by the method of allocating students to groups as previously described. The second assumption has been shown to be satisfied by calculation of an appropriate F value (largest variance for individual subgroup divided by smallest variance for individual subgroup). Finally there appears to be no need to check whether the distribution is normal or not since according to Lewis (1968) the F test is insensitive to lack of normality in the populations.

The method used to take account of the different numbers in the groups was that used by Popham and Sirotnik (1967).

The data is presented within the following sub-sections. An F ratio is calculated for three effects: first that due to the treatment on its own, to determine whether using the program had an effect on the dependent variable (the post-test); second that due to pre-testing on its own, to determine whether doing a pre-test had an effect on the dependent variable; and third that due to interaction between pre-testing and the treatment, to determine whether treatment and pre-testing taken together had an effect on the dependent variable.

The F ratio indicates whether an effect is significant or not, while the direction of the effect is indicated by the related means. These are recorded in the same tables together with the related standard deviations.

4.4.1 Effect of WELLS-PBAR Program on Student Learning

The analysis of variance data is shown in Table 5 for the WELLS-PBAR combined test.

None of the F ratios is significant, and it follows that the combined programs had no significant effect on student learning. It also follows that there were no interactions between the pre-testing and the treatment, and that pre-testing had no effect on student learning.

Table 5: Analysis of variance data for WELLS-PBAR combined test

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F Ratio	Probability
Main effects					
Treatment	3.544	1	3.544	0.647	N.S.
Pre-testing	5.839	1	5.839	1.066	N.S.
Interactions	3.798	1	3.798	0.693	N.S.
Within	290.398	53	5.479		
Total	303.579	56			

N.S. = Not Significant

Table 5 (continued) Analysis of variance data for WELLS-PBAR combined test

	Groups	No. of students	Mean	Std. Deviation
Treatment				
Given	O_2, O_5	32	7.06	2.21
Not given	O_4, O_6	25	6.56	2.48
Pre-test				
Given	O_2, O_4	25	6.48	2.31
Not given	O_5, O_6	32	7.13	2.34

4.4.2 Effect of MAXB Program on Student Learning

The analysis of variance data is shown in Table 6 for the MAXB test.

None of the F ratios is significant, and it follows that the MAXB program had no significant effect on student learning. It also follows that there were no interactions between the pre-testing and the treatment, and that pre-testing had no effect on student learning.

Table 6: Analysis of variance data for the MAXB test

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
Main Effects					
Treatment	18.150	1	18.150	1.854	N.S.
Pre-testing	0.100	1	0.10	0.01	N.S.
Interactions	0.310	1	0.31	0.03	N.S.
Within	548.290	56	9.791		
Total	566.850	59			

N.S. = Not Significant

Table 6 (continued) Analysis of variance data for the MAXB test

	Groups	No. of students	Mean	Std. Deviation
Treatment				
Given	O_2,O5	30	11.60	2.99
Not given	O_4,O_6	30	10.50	3.16
Pre-test				
Given	O_2,O_4	36	11.08	3.28
Not given	O_5,O_6	24	11.00	2.87

4.5 Discussion of results

In this experiment the students using the computer programs have been compared to students doing other activities, i.e., using different computer programs or doing laboratory experiments.

The results do not show any significant differences between those students who used the computer programs which were evaluated and those students who did not. This could either mean that the students did not learn from the computer programs or that the method of evaluation and the tests used in the evaluation were not sensitive enough to any differences that might have existed.

4.5.1 WELLS-PBAR Program

The most serious problem in the experiment arose from the fact that the WELLS-PBAR test was highly unreliable, with item analysis showing that only 8% of the variance of the combined test could be attributed to factors which are either common or specific to the test.

Hence it was highly unlikely that the analysis of variance would show any significant difference, because any differences would be swamped by 92% of the variance being due to error of measurement. One of the reasons for the low value of internal consistency is that the test consisted of only 7 items, 3 of which had poor discrimination indices.

It is also worth noting that the students did not hand in their post-tests immediately after the computer session, and this could have resulted in students exchanging views with one another thus reducing differences that might have been otherwise observed.

4.5.2 MAXB Program

The test for MAXB was much more reliable than that for WELLS and PBAR, having reliability of 0.67. One of the reasons for this was that the test contained 15 items, only 2 of which had poor discrimination indices. Thus the lack of significant differences between the groups suggests that the program did not help students in their understanding of the material

Again, it is worth noting that students may have exchanged views prior to responding to the post-test.

4.5.3 Constraints on Present Study

Two factors may have been responsible for the evaluation not finding any differences. First, one of the tests (see 4.5.1) was unreliable. Second, the number of students in the groups was small, even though all possible students taking part in the Summer School were used. This was partially due to the fact that the existing Summer School timetable could only be modified slightly, and partially due to the fact that all students had to ultimately receive the same overall experience, regardless of the schedule followed. As a result it was only possible to use two thirds of the students attending the SM351 Summer School. It is therefore suggested that firm conclusions should not be drawn before the study has been repeated on a more rigorous basis with improved tests and a larger number of students.

4.6 Suggestions for Improvement

4.6.1 Experiment Design for WELLS, PBAR and MAXB

With a repeat of the experiment in mind it is suggested that the experimental design might be improved by modifications in the timetable. This would entail curtailing the computer sessions slightly so that the post-tests could be completed under supervision. In addition there would be a second post-test at the end of the week again under supervision. Thus exchange of views between students could be prevented by the first post-test while the second would provide some measure of the degree to which any gain in learning was retained.

Some thought might also be given to the use of an alternative experimental method, such as the Time Series type of experiment, which does not require the student body to be split into smaller groups. Such an approach would overcome the statistical problem related to comparing small group sizes.

4.6.2 Dependent Variables

4.6.2.1 WELLS and PBAR test

Two test should be prepared, one test exclusively for WELLS and one test for PBAR thus permitting separate evaluation of the two programs. In an ideal situation each test would consist of twenty to twenty-five items. However, it is necessary to take note of the time it takes for students to answer the test when deciding how many items each test should include. A test with internal consistency of 0.7 or more, is desirable if significant differences in learning are to be observed.

4.6.2.2. MAXB test

Those items in the MAXB test which had poor discrimination indices should be modified and additional items written to increase the length of the test to at least twenty items.

CHAPTER 5

The Effect of three CAI Programs on Student Attitudes at Summer School

This chapter describes the experiment to determine student attitudes towards the programs.

5.1 Distribution of the Questionnaire

5.1.1. WELLS and PBAR Questionnaires

Questionnaires were distributed to all the students taking part in the Summer School once they had used the WELLS and PBAR programs. As shown in figure 1, page 47 , the questionnaires were distributed after all the post-tests had been collected, i.e. during the Wednesday session. Those students who were using the programs as the questionnaires were distributed were asked to complete them after they had used the programs. All the students were asked to return their completed questionnaires before the end of the week.

5.1.2 MAXB Questionnaire

As shown in figure 3, page 52 , the questionnaires were distributed to all the students after all the post-tests had been collected, i.e. during the evening session. Those students who were using the MAXB program at the time were asked to complete the questionnaire after they had used the program and before the end of the week.

5.2 Dependent variables

The questionnaires for the WELLS and PBAR programs are reproduced in section A3.1.1, appendix 3, and for the MAXB program in section A3.2.1, appendix 3. It will be noted that all three questionnaires consisted of several statements to which the students could agree or disagree on a five point scale. (A number of additional questions - not on the same five point scale - were included in the questionnaires, to obtain further information, but were not used to measure student attitudes.) The questionnaires concerning the WELLS and PBAR programs were identical, and were contained on the same form. The questionnaire for the MAXB program was similar to those concerning the WELLS and PBAR programs, but was different in that it asked specific questions with regard to the subject content of the program.

When the students were asked to respond on a five point scale they did so by writing a letter from A to E. To obtain the means, standard deviations and the item analysis data for this part of the questionnaire the responses were numerically coded.

For those statements which were positive about the programs (statements 1, 2 and 3 in the WELLS-PBAR questionnaire, statements 1, 2, 3, 4, 5 and 6 in the MAXB questionnaire) the coding was as follows

2 = A = Strongly agree
1 = B = Agree
0 = C = Uncertain
-1 = D = Disagree
-2 = E = Strongly disagree

For those statements which were negative about the programs (statements 4, 5 and 6 for the WELLS-PBAR questionnaire, statements 7, 8 and 9 for the MAXB questionnaire) the coding was in the reverse direction as follows:

-2 = A = Strongly agree
-1 = B = Agree
0 = C = Uncertain
1 = D = Disagree
2 = E = Strongly disagree

(Question 9 on the WELLS-PBAR questionnaire and question 11 on the MAXB questionnaire were not a part of the attitude measures, and were simply included to obtain additional information. The responses were in fact nominal in nature and although they were given a numerical coding[12] this was simply to facilitate the recording process.)

The raw data collected from the questionnaire responses is recorded in section A3.1.2. appendix 3 for WELLS and PBAR and section A3.2.2., appendix 3 for MAXB.

Item analysis of the questionnaires were used to check the reliability of the dependent variables. Only those statements on the questionnaires which could be answered on a five point scale were subjected to such analysis. The statistics obtained included the discrimination index for each statement and the internal consistency for each questionnaire.
(See chapter 4 pp. 55-58 for a discussion of item analysis.)

5.2.1 WELLS Questionnaire

All the six statements in the WELLS questionnaire had satisfactory discrimination indices as shown in section A3.1.3 in appendix 3. The internal

[12] This footnote is on the following page at the end of this section.

consistency for this questionnaire was 0.75.

5.2.2 PBAR Questionnaire

All the six statements in the PBAR questionnaire had satisfactory discrimination indices as shown in section A3.1.3 in appendix 3. The internal consistency for this questionnaire was 0.77.

5.2.3 MAXB Questionnaire

All the nine statements had satisfactory discrimination indices as shown in section A3.2.3 in appendix 3. The internal consistency was 0.73.

Item analysis thus showed that all three dependent variables were reliable measures of student attitudes towards the programs concerned.

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[12] The numerical coding used was as follows:
1 = No, 2 = Yes (at OU), 3 = Yes (but not at OU),
4 = Both (OU and not-OU)

5.3 The Effect of the CAI Programs on Student Attitudes

The mean student response to each questionnaire was determined by summing the responses of all the students to those questions, previously mentioned, which could be answered on a five point scale. For each questionnaire a null hypothesis was adopted which stated that the mean response would not differ significantly from zero. The means, standard deviations of the scores on the questionnaires and the probability of each mean are shown in Table 7 below.

Table 7: Means, standard deviations and probabilities of all three questionnaires.

Questionnaire	Mean	Std. Dev.	Probability
WELLS	4.4	4.1	< 0.001
PBAR	3.9	4.3	< 0.001
MAXB	2.8	5.3	< 0.01

From this it can be seen that students showed a significantly positive attitude to all three programs, with the most positive student attitudes being shown towards the WELLS program. Statistical comparisons are not made between student attitudes to the different programs, because Kerlinger (1964) suggests that in order to make these statistical comparisons it is necessary to establish that each statement on each questionnaire has an equal attitude value. In any repeat of this experiment this should be done with the help of a panel of experts.

Because the measures of student attitudes were based on the assumption that each statement had an equal attitude value, greater emphasis is placed on the following analysis of student responses to each statement on the questionnaire concerned. For each statement answerable on a five point scale a null hypothesis was adopted which stated that the mean response would not differ significantly from zero. The response to each statement was thus analysed in its own right, and was not dependent on each statement having the same attitude value as the other statements. The mean response for each statement, the standard deviation and the probability of each mean is recorded in tables 8 to 10, and the results are discussed in the following sub-sections.

5.3.1 WELLS Program

From Table 8, and the responses to questions 1 and 2, it appears that the students thought they understood the applications of the theory better after using WELLS and they thought the time spent at the terminal was a productive use of time. The response to question 3 concerning the future use of the program at Study Centres was not significant. The students significantly disagreed with questions 4, 5 and 6 which expressed reservations about the use of the computer.

Table 8: Means, Standard Deviations and Probability for WELLS statements.

Statement/Question	Mean	Std.Dev.	Probability
1. I think I understand the applications of the theory better now I have used this program	0.8	0.8	< 0.001
2. I think the time spent at the terminal was a productive use of time	0.8	1.0	< 0.001
3. If the facilities were available in the future at Study Centres I would use this program	0.2	1.2	N.S.
4. I felt the computer was in charge	1.0	1.0	< 0.001
5. During the work I was more involved in running the computer than in understanding the material	0.9	1.0	< 0.001
6. The method of instruction was too inflexible	0.6	1.1	< 0.001

5.3.2 PBAR Program

From Table 9 it will be seen that the PBAR program had an almost identical effect on student attitudes to that of the WELLS program. Thus the students thought they understood the applications of the theory better after using PBAR and they thought the time spent at the terminal was productive. Statement 3, about the future use of Study Centres, did not have a significant response. They significantly disagreed with statements 4, 5 and 6 which expressed reservations about the use of the computer.

Table 9: Means, Standard Deviations and Probability for PBAR statements.

Statement/Question	Mean	Std.Dev.	Level of significance
1. I think I understand the applications of the theory better now I have used this program	0.7	0.8	<0.001
2. I think the time spent at the terminal was a productive use of time	0.9	0.8	<0.001
3. If the facilities were available in the future at Study Centres I would use this program	0.3	1.2	N.S.
4. I felt the computer was in charge	0.8	1.1	<0.001
5. During the work I was more involved in running the computer than in understanding the material	0.7	1.2	<0.001
6. The method of instruction was too inflexible	0.6	1.1	<0.001

5.3.3. MAXB Program

The responses to the MAXB questionnaire were much more varied than those to the WELLS and PBAR questionnaires. However, from Table 10 it will be seen that after using the program students felt that they knew more about the way the distribution changed as the number of particles was altered. They also felt they knew more about how the frequency of occurrence of the most probable macrostate varied as the number of particles changed. The students felt the time spent at the terminal was a productive use of time. Also they did not think the computer was in charge.

In contrast the students did not appear to be significantly happier with Maxwell-Boltzmann statistics after they had used the computer than before. Not did they believe they knew significantly more about how the most probable macrostate influences the ensemble averaged distribution. They provided no significant indication that they would use the program in the future if facilities were available at Study Centres. Non-significant responses were obtained to two other statements, namely those concerned with whether the students were more involved in running the computer than in understanding the material, and whether the method of instruction was too inflexible.

Table 10: Means, Standard Deviations and Probability for MAXB statements.

Statement/Question	Mean	Std.Dev.	Level of significance
1. After using the computer simulation I felt that I was happier with Maxwell-Boltzmann statistics than before I used the computer.	0.2	0.9	N.S.
2. After using the simulation I felt I knew more about the way the distribution changes as the number of particles alters.	0.7	0.9	<0.001
3. After using the simulation I felt that I knew more about how the frequency of occurrence of the most probable macrostate varies as the number of particles changes.	0.4	0.8	<0.01
4. After using the simulation I felt I knew more about how the most probable macrostate influences the ensemble averaged distribution	0.1	0.9	N.S.
5. I felt the time spent at the terminal was a productive use of time.	0.6	1.0	<0.001

Table 10: (continued)

Means, Standard Deviations and Probability for MAXB statements

Statement/Question	Mean	Std. Dev.	Level of significance
6. If the facilities were available in the future at Study Centres I would use this program.	0.3	1.1	N.S.
7. I felt the computer was in charge	0.5	1.3	<0.05
8. During the work I was more involved in running the computer than in understanding the material	0	1.2	N.S.
9. The method of instruction was too inflexible.	0	1.1	N.S.

5.4 Discussion of results

5.4.1 WELLS and PBAR

Item analysis showed the WELLS and PBAR questionnaires to be reliable measures of student attitudes. It also showed that students have positive attitudes towards the use of the programs.

More detailed analysis of the responses to specific items in the questionnaires indicated that students disagreed with all those statements which expressed reservations about using the computer, and agreed with two of the three statements which were positive about the use of the programs.

With regard to the third positive statement which did not obtain significant student support it is worth noting that it asked students whether they would use the computer program concerned if facilities were available in future at Study Centres. In responding to this item it would appear that many do not normally go to Study Centres. Further, even if they found the existing program helpful they may not wish to use the same (as opposed to similar) program in the future.

5.4.2 MAXB

Item analysis showed the MAXB questionnaire to be a reliable measure of student attitudes. It also showed that students have positive attitudes towards the use of the program. The strength of student attitudes towards the MAXB program appeared to be less than that towards the WELLS and PBAR programs, and this was reflected in more varied responses to specific statements in the questionnaire.

Unlike the questionnaires concerning the WELLS and PBAR programs the MAXB questionnaire asked specific questions about the content presented in the program. Students indicated that they felt they knew more about the way the distribution changes, and the way the frequency of the most probable macrostate varies, as the number of particles changes. However, they did not indicate that they knew more about how the most probable macrostate influences the ensemble averaged distribution, nor did they indicate that they were any happier with Maxwell-Boltzmann statistics after using the program.

As with the WELLS and PBAR programs students did not indicate that they would use the MAXB program if it was available in future at Study Centres. Again this could be due to the fact that many students do not normally go to Study Centres, or because although they might feel inclined to use similar programs in future, they would not wish to use the same program again.

The one main difference to emerge between the programs was that students disagreed with the suggestion that the method of instruction used in WELLS and PBAR was too inflexible, but they did not disagree with the same statement concerning the MAXB program.

5.5 Suggestions for Improvement

The item analysis showed that the questionnaires were reliable measures of student attitudes. However, if they are to be re-used in the future, care should be taken to ensure that each statement had an equal attitude value, thus permitting more sophisticated comparisons between student attitudes to the programs. Further, in order to clarify the question of possible program usage in future related questions should be asked about student attendance at Study Centres, and attitudes towards subsequent use of similar programs as opposed to that of the existing programs. Questions concerning specific subject content might also be usefully included in any subsequent WELLS and PBAR questionnaires.

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[13]The numbers shown thus: ED 000 000, are the ERIC (Educational Resources Information Centers) reference numbers.

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Appendix 1

A more detailed description of programs used in the OU follows. The programs are classified in two ways: first within each mode by course reference code, and secondly alphabetically by program name. A number of programs are included within parentheses, because they appear to be more concerned with demonstrating programming skills than aiding instruction. Programs which are concerned with teaching computing have not been included.

The main reference for this appendix is the Student Computing Service Time Sharing Library Handbook.

The courses listed used CAI computer programs through the Student Computing Service during 1976. For conciseness, they are referred to by course code rather than by full title.

Course Code	Title
D222	Microeconomics
D281	New trends in geography
D291	Statistical sources
D301	Historical data and the social sciences
D305	Social psychology
E201	Personality and learning
E341	Methods of educational enquiry: an empirical approach
M100	Mathematics: a foundation course
M201	Linear mathematics
M321	Partial differential equations of applied mathematics
MDT241	Statistics: an interdisciplinary approach
MST281	Elementary mathematics for science and technology
MST282	Mathematics and applied calculus
S100	Science: a foundation course
S299	Genetics
ST285	Solids, liquids and gases
ST294	Principles of chemical processes
SM351	Quantum theory and atomic structure
T100	The man-made world: a foundation course
T241	Systems behaviour
T341	Systems modelling

A1.1 Classification by mode of Use

A1.1.1 Tutorial Mode

A1.1.1.1 Linear

Number	Course	Program Name
1	D305	DKELLY

This is a Kelly repertory grid package - an interactive analysis of attitudes to people or things.

(2	M100	DIFER

This is a differentiation test which has four levels of difficulty that are: simple functions, sums or differences of pairs of simple functions, products of pairs of simple functions and composition of pairs of simple functions.)

3	M100	DEMON

This program checks the answers to the practical exercises set in the laboratory texts of the computing units of M100.

4	M100	EXAM

This is a tutorial program which gives the student the choice between an easy introductory 'exam' paper and a full 'exam' paper. The questions in the tutorial are multiple choice type. The program provides answers to incorrect solutions if the student requests them.

Number	Course	Program Name
5	M100	MAP

This is another computerised tutorial. If the student does not know the answer on the first attempt he is given a hint and asked to try again.

6	MDT241	MDT241

This is a set of remedial tutorials on different units of the course. The tutorials ask the student multiple choice questions and wait up to eight minutes for a reply to each one. If a given answer is incorrect the student may have the answer printed.

7	MST281	MST281

This program is similar to MDT241 in that it is a remedial tutorial in which students have to answer multiple choice questions.

8	T100	LOG

This program provides a small amount of tuition in the use of logarithms, and then provides practice in their usage.

9	T100	POWERS

This program provides a small amount of tuition in the use of exponentials, and then provides practice in their usage.

Number	Course	Program Name
10	T100	TRIG

This is similar to the above two programs, but this time the subject area is trigonometry and Pythagoras' theorem.

A1.1.1.2 <u>Intrinsic</u>

1	M201	M201U7

This program is part tutorial part computation. The program is a teaching program which deals with recurrence relations. The students are presented with a set of questions. According to how well the student answers the program draws the student's attention to the points on which his understanding needs improving. This is done with the help of suitable hints, further questions, explanations and illustrations. The program then offers the student problems in the field of recurrence relations to solve, providing help or guidance if things go wrong.

2	M201	M201RT

This is a tutorial program for unit 7 of the course. There is a set of diagnostic questions. After answering these the students are given supplementary questions, suggestions on how to spend further time on the unit, diagnosis of difficulties and general feedback on performance.

Number	Course	Program Name	
A1.1.1.3 Adaptive			
1	S100	Acids and Bases	CALCHEM*

This program deals with the definition of acids and bases, titration curves and buffer actions. The definitions of acids and alkalis are discussed and the strength of an acid or base is related to the concentration of ions and to pH. The program includes questions to test students' knowledge.

2	S100	Bond Energies and Enthalpy Changes	CALCHEM[14]

The relationship between bond energies and enthalpy changes and the Morse curve are dealt with in this program. A diagram of the Morse curve is supplied to the students and questions are asked about the energy of a molecule at various points on the curve.

3	ST294	Planning an Experiment	CALCHEM[14]

This program is used part way through an experiment in which students measure the rates of radical reactions in the gas phase. In the first part of the experiment the student determines which substances are produced in a reaction which he is told to perform. Some surprising substances are found, so careful experiment planning is

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[14] See page 25 for a description of CALCHEM

Number Course Program Name

essential to determine the rates. All the students arrive at the planning stage at about the same time so that the tutor would find it impossible to deal adequately with his group of students without the program. The program questions the student about the sources of his products and leads him to the correct choice of products to analyse for. Each pair of students examines a different reaction, and the program is designed to test and advise for each reaction.

A1.1.2 Simulation Mode

1 E201 BRUNER

This program is to help students to perform experiments on themselves along lines similar to Bruner's original work on selection strategy. In this simulated experiment the students are provided with three sets of figures (circles, squares, triangles, etc.) which may be of different sizes, colour or shading and may include different numbers of figures in each set. The program allows the student to question whether particular figures are, or are not, examples of a particular concept, and may require students to identify the concept concerned.

2 M100 EXP1

This program has been devised to produce a random sequence simulating the results of an experiment in

Number	Course	Program Name

which a player guesses the suit of cards in a pack as they are turned over one at a time. After a series of guesses the user can ask for an analysis of the results so far.

3 M100/T100 MATCH

This game is to try not to be the one who removes the last 'match' from several rows of 'matches'.

4 M100 LANDER

This is a simulation of a rocket landing vehicle which lands on either the earth or the moon. The object is to land the vehicle without running out of fuel.

5 M100 TEASER

This is a puzzle the object of which is to solve a 3 x 3 matrix such that the 1s appear in all positions except the centre which has to be 0. The difficulty is that the student is not allowed to change an 0 to a 1 but must change 1s to 0s. When a 1 is made into a 0 its immediate neighbours change state.

6 M201 CGM201

This program provides an iterative table for a 2 x 2 game.

7 M201 SDM201

This provides an iterative table for a 3 x 3 game.

Number	Course	Program Name	
8	M201	TGM201	

This program prints an iterative table for a 3 x 3 game.

9	M321	RTT321	

This program models the pressure change down long thin tubes and solves by finite difference methods the non-linear partial differential equations produced.

10	S299	GDRIFT [15]	

This program simulates random genetic drift in a population. The student provides a set of initial values for the population and the program provides tables of values at different 'time' intervals.

11	S299	S299EV	Chelsea Science Simulation Project

This is a modification of a Chelsea simulation package. The simulation is concerned with genotypes.

12	S299	S299CO	Chelsea Science Simulation Project

This is another modified simulation package. In this case the simulation is about populations.

---

[15] S299 has not used this program in 1977.

Number	Course	Program Name	
13	S299	LNKOVR	Chelsea Science Simulation Project

This is a simulation program about the way in which family characteristics are inherited.

14	SM351	MEASUR

This program is a simulation of a simple harmonic oscillator obeying quantum mechanical rules. Two types of measurement can be simulated, and clarifying the distinction between them is one of the aims of the program. 'Repeated' measurements are those performed on identical initial states. The system is discarded after the measurement. In 'successive' measurements the system is not discarded. However it has been disturbed by the measurement, so now contains a different mixture of eigenstates. The nature of this mixture can be ascertained by making (repeated) measurements on the new system.

Both cases reflect the statistical nature of quantum systems. Thus a series of measurements, even of the repeated type, will all be different, but on drawing a frequency histogram of the results a clustering will be seen, allowing an estimate of the best value of the parameter, and the uncertainty in the value. Thus by making repeated measurements on a conjugate pair of variables, such as momentum and position, the 'uncertainty principle' can be demonstrated. This is another aim

Number	Course	Program Name

of the program.

15	T100	CARS

This program is part simulation part computation. It simulates a car going round a track with two corners of different radii. The student can choose one car from a list of ten cars, then 'drive' it round the track. The object is to determine the radii of the curves and the coefficient of friction at each curve. When the students have collected sufficient (as determined by the students) data about the speed at which the car skids at each of the corners, the program provides them with four equations with which they have to calculate the coefficient of friction at each bend and the radius of each bend. If the students do not have sufficient data when they try to calculate the results they can go back into the simulation mode.

16	T100	ALGORM

A series of instructions are provided which have to be linked together to form a flow chart which will enable the computer to print out the required result. The computer performs the instructions in the order specified by the students. If the results are incorrect a correct set of results is printed out.

Number	Course	Program Name
17	T100	LUNAR

This program simulates landing a lunar module on the moon. A set of instrument readings of altitude, vertical speed, vertical acceleration and fuel level is provided. Students have control over the setting of the throttle. The instrument readings are printed out at intervals specified by the student and changes in the throttle setting can take place at those time intervals.

18	T100	STATS

This program simulates the behaviour of a machine packing goods with a declared weight. The weights of the packs are liable to random variation and machine drift. The student has to vary the settings of the 'machine' to keep the weight of the packs within specified limits at the same time trying to keep the weight of the packs as small as possible.

19	T241	MANSIM

This is a computerised version of a manual simulation of a container pack which the students have already encountered. The students have to provide details of the number of lorries, the number of lorries on journeys and the number of cleared containers in the park. The program simulates some of the activities in the park over a specified period of time.

Number	Course	Program Name
20	T241	SIMSTR

This program is an exercise on the strategy of simulation. Its objective is to demonstrate the problems of using simulation methods to find a 'best' answer to a specific problem. The student has to assume that an event sequenced simulation is available. The student has to find the optimum size of a container park and its throughput. Optimum here means the conditions which will give the lowest cost per container. It is not possible for the students to simulate every possible combination of park size and throughput because of limitations of computer time. A program is run through before the students use the computer and the results of the simulation are entered in the computer. Hence when the student specifies the parameters the value of the cost per container is output from memory for those parameters.

21	T241	LEVEL

This is a simulation of a hydraulic control exercise which the students perform in the unit. The students vary several parameters and receive the effect of the variations on the hydraulic system.

Number	Course	Program Name
22	T241	DIFF

This program uses either a differential equation model or a difference equation model to conduct a simulation of a biological problem. The program simulates the behaviour of the two component plant-herbivore system supplied to the students in their home kits. The students can vary the two parameters on which depend the growth rate of two species in the system. The program reproduces several features of an analogue simulation which students viewed on TV.

23	T241	MACE

This program uses a transition matrix model to simulate a population of organisms. Students enter the number of age classes in the population and the probability of survival for one organism from one age class to the next. They also enter the initial numbers of organisms in each age, class and the number of populations to be simulated. The output from the simulation is a table giving the numbers in each age class for all generations; additionally, the ratios of the numbers between population age classes are calculated for the last two simulated generations.

Number	Course	Program Name
24	T341	SIM341

This is a derivation from a program developed at Hatfield Polytechnic. It simulates a wide variety of systems. The method used is an extension of a manual simulation used in the unit. Some of the systems are; a supermarket, a garage, a factory and a colliery. The students have to provide details of the activities involved in the simulation.

A1.1.3 Calculational Experiment Mode

1	D291	POPRO

This will carry out the calculations for a population projection. The student has to enter population figures for a particular year and the program then calculates the projected population for a five year period. The student can then change the birth rate or the death rate.

2	D291	INDEX

This program enables the student to make various calculations concerning the Retail Price Index. The student can vary the relative prices of commodities and their weighting factors to obtain a Retail Price Index.

3	ST285	PATHS

Students use this program to investigate the concepts of path dependent and path independent quantities. The

Number	Course	Program Name

students supply the values of the initial and final conditions. The program computes the change in temperature and the mechanical work done in taking a mass of substance between the initial and final conditions by three different paths.

4	ST285	ENGIN

This program allows the students to use the first law of Thermodynamics to evaluate the thermal efficiency of a heat engine operating a Stirling cycle. Students specify one of two working fluids and the values of pressure and molar volume at the high pressure and low pressure points in the cycle. The program calculates the thermal efficiency, the temperatures at different parts of the cycle and the work delivered per cycle.

5	ST285	MAXB

This program simulates a model of a gas which the students have previously seen. See Chapter 3 for more details of this program.

6	SM351	WELLS

This program enables a student to find the eigenvalues and eigenfunction of square well and harmonic oscillator quantum mechanical potential wells.

See Chapter 3 for a more detailed description of this program.

Number	Course	Program Name	
7	SM351	PBAR	CUSC[16]

This program uses a graphics terminal to display what occurs (in terms of waves) when a particle is incident upon either a potential barrier or a potential well. See Chapter 3 for a more detailed description of this program.

8	SM351	RUTHER	CUSC[16]

This program deals with the interaction between a moving particle and a stationary particle as is the case in Rutherford scattering. The parameters which can be varied are the velocity and impact parameter of the moving particle and the charge of the stationary particle. The trajectory of the moving particle is displayed on a graphics terminal.

A1.1.4 <u>Computation</u>

1	D222	D222LP

This solves the standard linear programming problem of maximisation and minimisation.

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[16] CUSC: Computers in the Undergraduate Science Curriculum is an inter-university project funded by the National Development Programme in Computer Assisted Learning. The participating institutions are: University College London, Chelsea College London and the University of Surrey.

Number	Course	Program Name
2	D281	CLUST [17]

This program attempts to produce a Single Link Cluster list from an Inter point distance Matrix. However, the program only removes 'obvious' multiple links and does not do a true Single Link Cluster Analysis. Thus the user has to draw his own linkage tree to remove the extra redundant links.

3	D281	TRENDS [17]

This provides an analysis of spatially distributed data where the analysis of such data is in terms of attempting to extract generalisations from data sets containing errors. The program uses the method of multiple regression by least squares to compute and print up to third order trend surfaces.

4	D281	GETIS [17]

This is a special significance test designed for the D281 Summer School

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[17] D281 has been withdrawn from the Social Sciences faculty's profile in 1977.

Number	Course	Program Name
5	D291	ROOMS

This program is designed to give a more accurate estimate of the numbers of persons living in crowded or sparse conditions than is available from published tables of occupancy. The student can supply his own occupancy table for a particular area, or a demonstration run using stored data can be used. A histogram and table of occupancy are printed out. The student can then set the parameters which define crowding. The computer prints out specific information about the data such as the number of crowded conditions and the average size of crowded households.

6	D291	GINI

This program calculates a specific coefficient for a set of data. This coefficient is called the Gini coefficient.

7	D301	HIST

This program calculates the mean, median, mode, upper and lower quartiles and standard deviation of a set of data. A histogram of the data is printed and the user has the option of testing the data against the normal distribution using a chi-square test.

Number	Course	Program Name
8	D301	MOVAV

This calculates the moving average over any period for simultaneous observations on up to five variables. The number of observations used to calculate the average is chosen while the program is running.

9	D301/E341 /E201	CORR4

This program calculates four different correlation coefficients. They are: mean square contingency coefficient, Spearman's rank order correlation coefficient, Tetrachoric correlation coefficient and Pearson's product moment correlation coefficient.

10	D301/E341	CORMAT

This program calculates the product moment correlation coefficients for up to 25 variables.

11	D301/E341	INDT

This computes the mean difference, standard error of difference of means and the t ratio for two samples of uncorrelated scores.

Number	Course	Program Name
12	D301/E341	CORRT

This computes the standard error of the mean of pair differences and the t ratio for two samples of correlated scores. The maximum number of scores in each sample is 50.

13	D301/E341	ANVAR1

This computes an analysis of variance table for a number of groups of observations in a single variable.

14	D301/E341	MULCOR

This program calculates one or more multiple correlations of a dependant variable with a number of independant variables.

15	D301/E341	CHISQS

This program computes chi-square values for a number of contingency tables.

16	D301	LSQFIT

This program produces a least squares fit to the following functions:

$Y = A+Bx$, $Y = Ae^{Bx}$, $Y = Ax^{B}$, $Y = A+(B/x)$, $Y = 1/(A+Bx)$, $Y = x/(A+Bx)$, $Y = A+B\log x$, $Y = AB^{x}$. After the students have input their data a table is printed giving for each of the eight functions the values of A and B and a parameter which gives a measure of the variation of

Number	Course	Program Name

students supply the values of the initial and final conditions. The program computes the change in temperature and the mechanical work done in taking a mass of substance between the initial and final conditions by three different paths.

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6	D291	GINI

This program calculates a specific coefficient for a set of data. This coefficient is called the Gini coefficient.

7	D3O1	HIST

This program calculates the mean, median, mode, upper and lower quartiles and standard deviation of a set of data. A histogram of the data is printed and the user has the option of testing the data against the normal distribution using a chi-square test.

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Number	Course	Program Name

the Y values that is explained by that function.

The students can then obtain more details for any of the functions. The details are presented in a table which gives for each x value; the actual Y value, the Y value calculated using the function and the difference between the actual and the calculated Y value.

17 D301/E341 KR20

For an examination or test which they have administered students can use this program to find the following data: the difficulty (facility) index, the discrimination index, the variance of each item, the sum of the variances of the separate test items, the variance of the test scores, the average difficulty (facility) index of the test items, the average discrimination index of the test items and the Kuder-Richardson formula 20 coefficient, ie. a measure of the test's internal consistency reliability.

18 M100 EUCLID

This program finds the largest common factor of two integer numbers.

19 M100 ROWOP

This program allows elementary row operations to be performed on a matrix.

Number	Course	Program Name
(20	M100	SORT

This program sorts a list of numbers into ascending order.)

(21	M100	EVAL

This program iteratively evaluates the exponential function.)

(22	M100	PFACT

This program finds the prime factor and multiplicity of an integer.)

(23	M100	PLEQ

This is a sub-routine which solves a pair of linear equations.)

24	M100	ROUTE

This program finds a route through a specified matrix.

(25	M100	SEQGEN

This program provides a sample solution to an algorithm given in the text of the course.)

(26	M100	TABWVH

This program holds a list of heights and weights. It prints them out and then lists the number of subjects with similar heights and weights and the averages.)

Number	Course	Program Name
27	M201	BRM201

This is a program to evaluate a specific integral by a backwards recurrence relation.

28	M201	CHM201

This program computes the coefficients of a Chebyshev expansion in an interval of a function. The student may define the function but if the student does not define the function then it will be e^x.

29	M201	DEM201

This program uses four different numerical methods to solve a specific equation.

30	M201	EVM201

This program computes Eigensolutions of a given matrix using the method of direct iteration.

31	M201	FOM201

This program calculates the coefficients of a Fourier approximation in an interval of a function defined by the student. If the student does not define a function then it will be e^x.

32	M201	FRM201

This program evaluates a specific interval by a forward recurrence relation.

Number	Course	Program Name
33	M201	GEM201

This program solves a set of linear equations using Gaussian Elimination both with and without changes.

34	M201	IIM201

This program computes Eigensolutions of a given matrix using the method of inverse iteration.

35	M201	LCM201

This is a program to calculate a classical least squares approximation of e^x in a specific interval. The function can be amended by the student.

36	M201	LLM201

This program gives the coefficients of a least squares approximation by Legendre Polynomials in a specific interval. The function can be defined by the student but it will be e^x if not defined by the student.

37	M201	LPM201

This solves linear programming problems by elementary row operations.

38	M201	MPM201

This program accepts input of a matrix row by row and performs elementary row operations.

Number	Course	Program Name
39	M201	SEM201

This computes a specific integral from a series expansion.

40	M201	SIM201

This computes the same integral as used in SEM201 but this program uses Simpson's rule.

41	M201	TOM201

Computes a Sturm sequence for a tridiagonal matrix

42	M201	U21DEM

This program deals with the numerical solution of differential equations.

43	M321	EXP321

This program evaluates, by numerical methods, a partial differential equation for heat conduction.

44	M321	CNH321

Numerical methods are used to solve a second order differential equation subject to initial conditions.

45	M321	COM321

This program compares the efficiency of different finite difference schemes in the solution of a particular problem.

Number	Course	Program Name
46	M321	SOR321

This solves a matrix equation by a particular method.

47	M321	TRI321

This is a program to solve a system of tridiagonal linear equations.

48	MDT241	EDCALC

This program provides the students with the facility of a programmable desk calculator. The 'calculator' has one working register and 24 storage registers.

(49	MST281	BASIC

This system has been designed to help run and correct programs written in a subset of the BASIC language.)

50	MST281	SIMINT

This is a program to carry out a numerical integration of a student defined function using Simpson's rule.

51	MST282	TYM282

This numerically solves a first order differential equation using Taylor's series.

52	MST282	EUM282

This program numerically solves a first order differential equation using Euler's method.

Number	Course	Program Name
53	MST282	EMM282

This uses a modification of Euler's method to numerically solve a first order differential equation.

54	MST282	D2M282

This solves second order differential equations using Taylor's series.

55	S100	CHEM1

This program is designed to check students' calculations in a Summer School experiment. The students do the calculations first and then feed their raw data into the computer.

56	S100	CHEM2

This program stores the results which the students have presented in CHEM1. It is designed to be used by the tutor to enable him to obtain a complete summary of the results of the session.

57	S100	S100EX

This checks the students' answers to the specimen examination paper.

58	S299	MENDEL [18]

An interactive program which calculates chi- square and

[18] S299 has not used these programs in 1977

Number	Course	Program Name

the associated probability for the results of a genetics experiment.

59	S299	TOMATO [18]

This interactive program calculates chi-square and probabilities for students' results from a home experiment.

60	ST285	BBEQS

Calculates the critical isotherm of Argon using the Beattie-Bridgman equation of state.

61	ST294	Calc. of Equilib.Constant CALCHEM[19]

This checks the student's calculation of an equilibrium constant. If the answer is incorrect the computer tests that the choice of data is correct and then proceeds, if necessary, to locate the error.

62	ST294	Thermodynamics CALCHEM[19]

This program is used to make a series of tedious calculations for students when they have demonstrated their understanding and ability to perform one calculation.

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[19] See page 25 for a description of CALCHEM.

Number	Course	Program Name
63	T100	GRAPHS

This program draws graphs of five mathematical functions, e.g. Y = Asin (wx).

64	T100	TRUTH

This program provides a truth table of any Boolean expression up to nine variables.

65	T100	Programming Option

This option is intended to serve as a guide to the specifics of the BASIC language. It is not intended to teach those students who do not know anything about computing.

66	T241	LEON

The program LEON generates an input-output table from information on intersectoral-transactions supplied by the students.

67	T241	REG

This performs a least-squares regression analysis on data provided by the students.

68	T341	T341LP

This program is designed to solve linear programming problems. It splits into three phases; the input phase, the option phase and the solution phase.

Number	Course	Program Name
69	T341	T341UT

This program evaluates the users utility function.

A1.1.5 Learner-controlled

1	T341	IDA

This program, which was developed at Chicago University, provides interactive data analysis on data supplied by the students. The data supplied to the computer has to be in the form of an array. There are many commands available to the user. Some of them are; plotting a histogram, printing a variable, printing a scatter plot between any two variables, obtaining means and standard deviations, transformation of variables, simple linear regression and multiple regression. It can be termed part computation as well as learner-controlled.

A1.2 Alphabetical Classification of Programs

Program Name	Location	
Acids and Bases	adaptive	1
ALGORM	simulation	16
ANVAR1	computation	13
BASIC	computation	49
BBEQS	computation	60
Bond Energies and Enthalpy Changes	adaptive	2

Program Name	Location	
BRM201	computation	27
BRUNER	simulation	1
Calc. of Equilib.Constant	computation	61
CARS	simulation	15
CGM201	simulation	6
CHEM1	computation	55
CHEM2	computation	56
CHISQ	computation	15
CHM201	computation	28
CLUST	computation	2
CNH321	computation	44
COM321	computation	45
CORMAT	computation	10
CORRT	computation	12
CORR4	computation	9
DEMON	linear	3
DEM201	computation	29
DIFF	simulation	22
DIFFER	linear	2
DKELLY	linear	1
D2M282	computation	54
D222LP	computation	1
EDCALC	computation	48
EMM282	computation	53
ENGIN	calculational experiment	4
EUCLID	computation	18

Program Name	Location	
EUM282	computation	52
EVAL	computation	21
EVM201	computation	30
EXAM	linear	4
EXP1	simulation	2
EXP321	computation	43
FOM201	computation	31
FRM201	computation	32
GDRIFT	simulation	10
GEM201	computation	33
GETIS	computation	4
GINI	computation	6
GRAPHS	computation	63
HIST	computation	7
IDA	learner-controlled	1
IIM201	computation	34
INDEX	calculational experiment	2
INDT	computation	11
KR20	computation	17
LANDER	simulation	4
LCM201	computation	35
LEON	computation	66
LEVEL	simulation	21
LLM201	computation	36
LNKOVR	simulation	13
LOG	linear	8

Program Name	Location	
LPM201	computation	37
LSQFIT	computation	16
LUNAR	simulation	17
MACE	simulation	23
MANSIM	simulation	19
MAP	linear	5
MATCH	simulation	3
MAXB	calculational experiment	5
MDT241	linear	6
MEASUR	simulation	14
MENDEL	computation	58
MOVAV	computation	8
MPM201	computation	38
MST281	linear	7
MULCOR	computation	14
M201RT	intrinsic	2
M201U7	intrinsic	1
PATHS	calculational experiment	3
PBAR	calculational experiment	7
PFACT	computation	22
Planning an Experiment	adaptive	3
PLEQ	computation	23
POPRO	calculational experiment	1
POWERS	linear	9

Program Name	Location	
Programming Option	computation	65
REG	computation	67
ROOMS	computation	5
ROUTE	computation	24
ROWOP	computation	19
RTT321	simulation	9
RUTHER	calculational experiment	8
SDM201	simulation	7
SEM201	computation	39
SEQGEN	computation	25
SIMINT	computation	50
SIMSTR	simulation	20
SIM201	computation	40
SIM341	simulation	24
SORT	computation	20
SOR321	computation	46
STATS	simulation	18
S100EX	computation	57
S299CO	simulation	12
S299EV	simulation	11
TABWVH	computation	26
TEASER	simulation	5
TGM201	simulation	8
Thermodynamics	computation	62
TOMATO	computation	59
TOM201	computation	41
TRENDS	computation	3

Appendix 2: Tests

This appendix contains details of the tests used in the experiment described in Chapter 4. Item analysis data for these tests is included together with a discussion of the item analysis.

A2.1 WELLS and PBAR Test

A2.1.1 Test Paper

Answer The Questions by Ringing The Appropriate Entries in The Keys

Q.1

Consider a particle in the n^{th} state of an harmonic oscillator of square well potential. At how many points inside the classical limits will be particle never be found? (The ground state corresponds to n = 1).

A n-1

B n

C n+1

D 2n-2

E Depends on the well

Q.2

How does the ground state energy of a finite square well change when the height of the well is increased?

A It remains constant

B It decreases

C It increases

Q.3

A particle has energy E_1 in the ground state of a certain infinite square well and is described by a wave function of even parity. Which two of the following combinations of energy and parity are possible for the particle in an excited state of the well?

A Energy $2E_1$ and odd parity

B Energy $4E_1$ and even parity

C Energy $4E_1$ and odd parity

D Energy $64E_1$ and even parity

E Energy $64E_1$ and odd parity

Q.4

A particle has energy E_1 in the ground state of a certain harmonic oscillator potential and is described by a wavefunction of even parity. Which two of the following combinations of energy and parity are possible for the particle in an excited state of the well?

A Energy $3E_1$ and odd parity

B Energy $4E_1$ and even parity

C Energy $5E_1$ and odd parity

D Energy $6E_1$ and even parity

E Energy $7E_1$ and odd parity

Q.5

Must reflection always occur when a travelling wave is incident on a potential well?

A Yes

B No

C Don't know

Q.6

Must reflection always occur when a travelling wave of energy E is incident on a barrier of height $V_o > E$?

A Yes

B No

C Don't know

Q.7

A travelling wave of energy E is incident on a barrier of height V_o and width a. The transmission co-efficient is T. Which two of the following statements are false, when $\infty > V_o > E > 0$.

A $1 > T > 0$

B T is an increasing function of E

C T is an increasing fucntion of V_o

D T is an increasing function of a

E The wave function inside the barrier involves exponential functions

A2.1.2 Item Analysis Data

Internal consistency	0.08
Standard Error	2.28
Error Ratio	0.96
Standard deviation of Facility Index	4.2
Standard deviation of Discrimination Index	13.2

Item \ Index	FACILITY	DISCRIMINATION
1	55	19*
2	55	19*
3	58	84
4	58	89
5	47	11*
6	49	46
7	75	40

*Items with unsatisfactory discrimination indices.

A2.1.3 Analysis of Items

There were four major factors which affected the item statistics in this test. The factors are:

1. The small number of students, i.e. 57, this meant that the standard deviation of the Discrimination index was 13.

2. The limited number of items in the test, this was a crucial factor in the poor internal consistency value.

3. The inclusion of 1 from 2 or 1 from 3 items (there were 3 one from 2 or 3 items in the test). It is impossible to tell why some students choose the wrong answer in this sort of question.

4. The questions with a different format, i.e., select 1 or 2 from several, in general had better statistics.

Individual items with unsatisfactory statistics

Q1.	Facility Index	55
	Discrimination Index	19

% of responses for each option

A*	56
B	5
C	16
D	0
E	19
Don't know	4

*Correct option.

In this case the format should produce acceptable statistics but distractor E is taking a large percentage of the responses. Distractor E is 'depends on the well', this distractor may be too general and should be modified to be more specific to the question.

Q 2	Facility Index	55
	Discrimination Index	19

% of responses for each item

A	32
B	7
C*	58
Don't know	4

*Correct option

Distractor A is attracting too many students for the item to produce acceptable statistics. However it is difficult to see what is wrong with the question.

Q5. Facility Index	47
Discrimination Index	11
% of responses for each option	
A	25
B*	70
Don't know	5

*Correct option.

As this question is of the select 1 from 2 variety it is difficult to determine what caused some of the students to answer the wrong answer. However there is some ambiguity in the question because students are not told whether the reflection refers to the particle or the wave associated with the particle. A further factor in this question is the low value of the facility index which would affect the discrimination index.

A2.2 MAXB Test

A2.2.1 Test Paper

All the questions concern a gas of point particles at temperatures greater than absolute zero in a box with perfectly reflecting walls (in equilibrium).

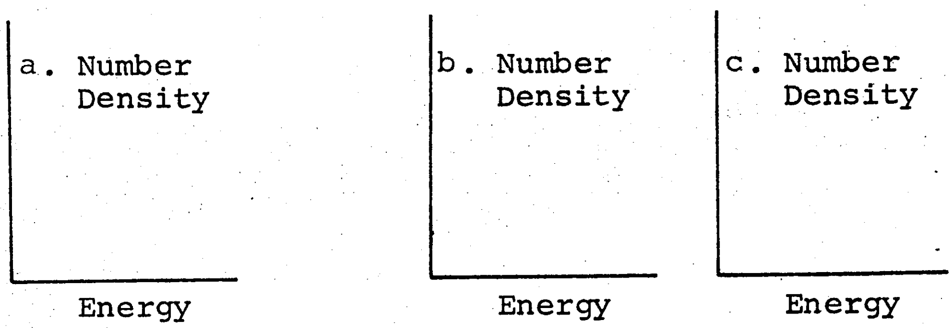
Q1 (Objective 1)

Sketch on the axes provided an energy distribution for the following cases:

(a) A very large number of particles (10^{23} particles);

(b) A small number of particles (fewer than 10);

(c) Only one particle.



Q2 (Objective 2)

In the following three situations crudely estimate the ratio of the probabilities of the most probable macrostate and the next most probable macrostate.

		ANSWER
(a)	10 Particles;	______
(b)	40 Particles;	______
(c)	10^{23} Particles.	______

Choose your answers from the KEY:

A The most probable macrostate occurs only slightly more frequently than the next most probable macrostate.

B The most probable macrostate occurs 10 times more frequently than the next most probable macrostate.

C The most probable macrostate occurs 1000 times more frequently than the next most probable macrostate.

D The most probable macrostate occurs 10^6 times more frequently than the next most probable macrostate.

Q3 (Objective 3)

This question explores your understanding of the closeness of fit of the ensemble averaged distribution and the most probable macrostate to the Maxwell- Boltzmann distribution. Complete the sentences (a) to (c) below by choosing one of the statements in the KEY:

	ANSWER
(a) When there are a very small number of particles	______
(b) When there are 40 particles	______
(c) When there are 10^{23} particles	______

KEY

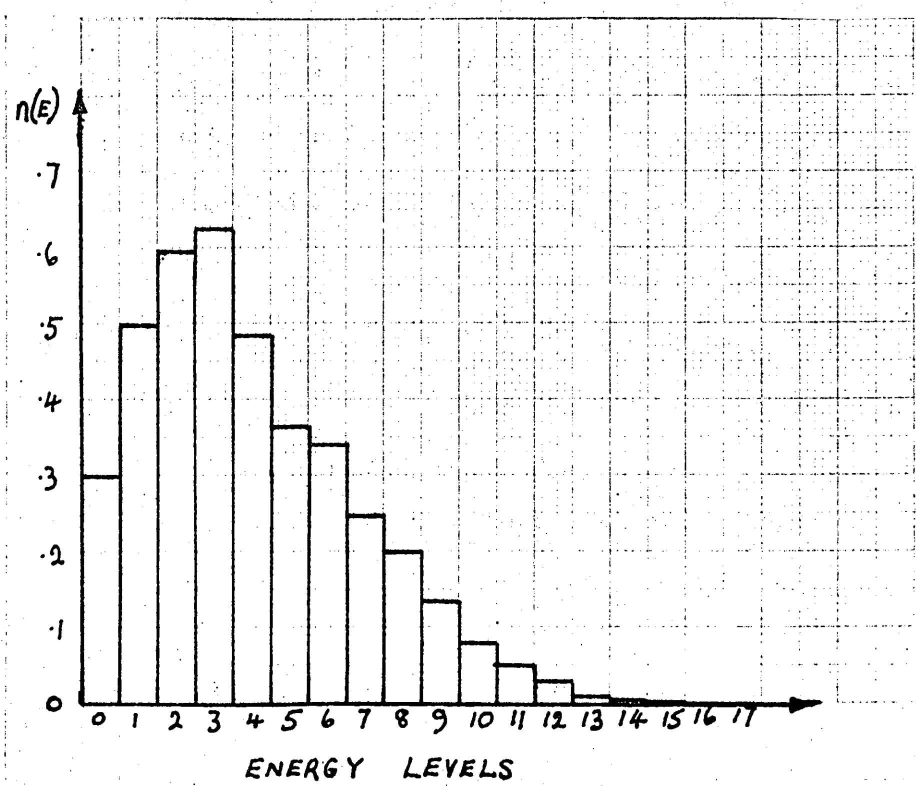
A The ensemble averaged distribution is more like the Maxwell- Boltzmann distribution than the most probable macrostate.

B The ensemble averaged distribution is less like the Maxwell-Boltzmann distribution than the most probable macrostate.

C The ensemble averaged distribution is almost the same as the most probable macrostate.

Q4 (Objective 1)

Considering the bookshelf model as described in Unit 4, if you have four particles and a total energy of sixteen you might expect the ensemble-averaged distribution to be as shown below. However if instead of four particles there were forty particles, with the number of energy levels and total energy the same, what would you expect the main differences between the distributions to be? Choose four from the list below.



TICK up to 4 boxes:

☐ (a) The distribution is smoother.

☐ (b) The peak of the distribution is shifted to higher energy.

☐ (c) The peak of the distribution is shifted to lower energy.

☐ (d) The peak of the distribution stays at approximately the same energy.

☐ (e) The distribution fits more closely to the Maxwell-Boltzmann distribution.

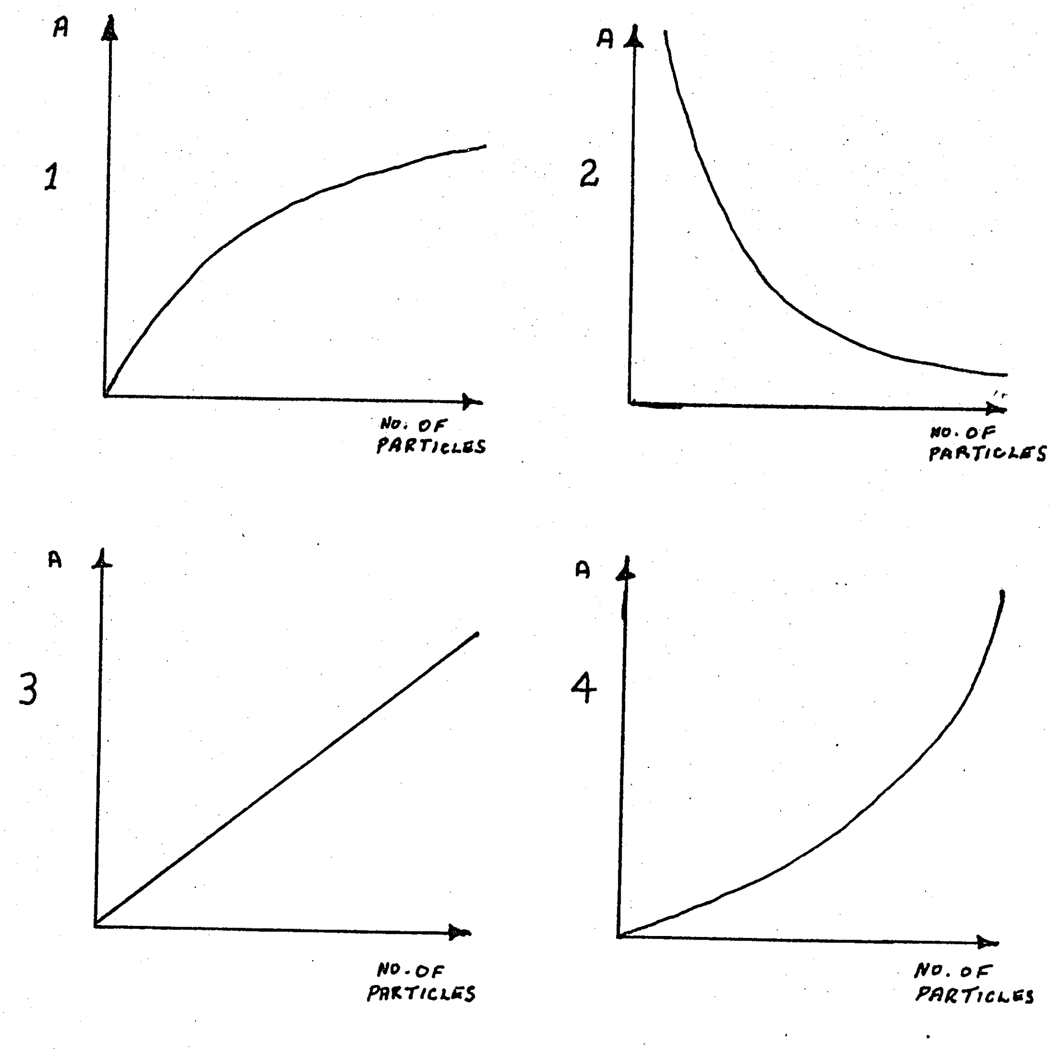
☐ (f) The tail of the distribution reaches to higher energy.

☐ (g) The tail of the distribution meets the energy axis at lower energy.

☐ (h) The tail of the distribution meets the energy axis at approximately the same energy as before.

Q5 (Objective 2)

Let A equal the ratio of the frequency of occurrence of the most probable macrostate to the frequency of occurrence of the next most probable macrostate. A is plotted against the number of particles in the distribution in the following four figures. Choose the <u>one</u> you think correct.



Q6 (Objective 3)

This question explores your understanding of how the most probable macrostate of a distribution of particles affects the ensemble-averaged distribution of those particles. Complete the sentences (a) to (d) below by choosing one of the statements in the KEY.

		ANSWER
(a)	When there are a very few particles	_____
(b)	When there are 10 particles	_____
(c)	When there are 40 particles	_____
(d)	When there are 10^{23} particles	_____

KEY

A The most probable macrostate occurs with almost the same frequency as the next most probable macrostate and hence the ensemble-averaged distribution is not greatly influenced by the most probable macrostate.

B The most probable macrostate occurs more frequently than the next most probable macrostate and hence the ensemble-averaged distribution is moderately influenced by the most probable macrostate.

C The most probable macrostate occurs overwhelmingly more frequently than the next most probable macrostate and hence the ensemble-averaged distribution is virtually the same as the most probable macrostate.

A2.2.2 Item Analysis Data

Internal consistency	0.67
Standard error	1.80
Error ratio	0.58
Standard deviation of Facility Index	4.1
Standard deviation of Discrimination Index	12.9

INDEX / ITEM	FACILITY	DISCRIMINATION
1a	75	17*
1b	28	24*
1c	57	46
2a	70	43
2b	59	49
2c	61	33
3a	41	46
3b	35	41
3c	50	43
4	56	67
5	61	52
6a	70	69
6b	70	61
6c	69	37
6d	68	62

*Items with unsatisfactory discrimination indices

A2.2.3 Analysis of Items

Only two items in this test had unsatisfactory discrimination indices. However the same comments as apply to the WELLS-PBAR test apply to this test regarding the number of students in the test and the standard deviation in the discrimination index. The standard deviation is still 13.

The two questions which had poor statistics were questions 1a and 1b. Both these questions can be considered as select 1 from 2 type questions. It is not possible to determine why some of the students drew an incorrect sketch.

Appendix 3: Questionnaires

The appendix contains the questionnaires used in the experiment described in chapter 5.
The raw data from these questionnaires is shown together with the item analysis data for them.

A3.1 WELLS and PBAR Questionnaires

A3.1.1 Questionnaire paper

Please reply to statements 1 to 6 by writing a letter in the relevant column. Write the letter

A- if you strongly agree

B- if you agree

C- if you are uncertain

D- if you disagree

E- if you strongly disagree

with the following statments.

	WELLS	PBAR
1. I think I understand the applications of the theory better now I have used this program.		
2. I think the time spent at the terminal was a productive use of time.		
3. If the facilities were available in the future at Study Centres I would use this program.		

A3.1.1. Questionnaire paper (continued)

	WELLS	PBAR
4. I felt that the computer was in charge.		
5. During the work I was more involved in running the computer than in understanding the material.		
6. The method of instruction was too inflexible.		

---

7. How long did the interaction take you?

8. How many people (students and tutors) did you work with at the terminal. (Only count those who stayed for most of the time)

A3.1.1. <u>Questionnaire paper</u> (continued..)

9 Have you used a computer before you came to this Summer School? (Circle your reply)

NO   YES (at OU.)   YES (but not at OU.)

10. If your answer to Q9 is YES - did you write the computer program or did you use a computer program already in existence?

....

11. Were there any technical problems with the computer (e.g. bad phone lines)? YES/NO.

If YES, please specify.............................

Thank you for answering this questionnaire:
if you have any further comments to make will you please do so in the space below.

A3.1.2 Raw Data

Statement/Question	WELLS								PBAR							
	No. of Responses						Mean	STD Dev	No. of Responses						Mean	STD Dev
	2(A) Strongly Agree	1(B) Agree	0(C) Uncertain	-1(D) Disagree	-2(E) Strongly Disagree	Total			2(A) Strongly Agree	1(B) Agree	0(C) Uncertain	-1(D) Disagree	-2(E) Strongly Disagree	Total		
1. I think I understand the applications of the theory better now I have used this program	11	52	7	8	1	79	0.8	0.8	7	41	14	7	1	70	0.7	0.8
2. I think the time spent at the terminal was a productive use of time	17	43	10	7	2	79	0.8	1.0	14	38	13	3	1	69	0.9	0.8
3. If the facilities were available in the future at Study Centres I would use this program	13	23	20	16	7	79	0.2	1.2	10	21	21	12	6	70	0.3	1.2

A3.1.2 <u>Raw Data</u> (continued)

Statement/Question	WELLS								PBAR							
	No. of Responses						Mean	STD Dev	No. of Responses						Mean	STD Dev
	-2(A) Strongly Agree	-1(B) Agree	0(C) Uncertain	1(D) Disagree	2(E) Strongly Disagree	Total			-2(A) Strongly Agree	-1(B) Agree	0(C) Uncertain	1(D) Disagree	2(E) Strongly Disagree	Total		
4. I felt the computer was in charge	2	7	3	40	26	78	1.0	1.0	4	7	6	32	20	69	0.8	1.1
5. During the work I was more involved in running the computer than in understanding the material	3	9	4	42	21	79	0.9	1.0	6	8	5	33	18	70	0.7	1.2
6. The method of instruction was too flexible	3	12	15	32	16	78	0.6	1.1	3	9	12	29	15	68	0.6	1.1

A3.1.2 Raw Data (continued)

Statement/Question	WELLS Total No. of Responses	WELLS Mean	WELLS STD Dev	PBAR Total No. of Responses	PBAR Mean	PBAR STD Dev
7. How long did interaction take you? (Mins)	53[20]	70.43	38.32	44[10]	50.41	36.69

Statement/Question		WELLS No. of Responses					WELLS Mean	WELLS SD	PBAR No. of Responses						PBAR Mean	PBAR SD
	0	1	2	3	4	Total	Mean	SD	0	1	2	3	4	Total	Mean	SD
8. How many people (students) and tutors) did you work with at the terminal?	21	37	14	1	1	74	.97	.81	17	30	18	0	0	65	1.02	0.74

Statement/Question	WELLS No. of Responses					PBAR No. of Responses				
	(1) No	(2) Yes (at OU)	(3) Yes (But not at OU)	(4) Both	Total	(1) No	(2) Yes (at OU)	(3) Yes (But not at OU)	(4) Both	Total
9. Have you used a computer before you came to Summer School?	3	52	16	8	79	3	44	5	18	70

[20] Several students interpreted this as the time it took for the computer to respond to their input.

A3.1.3 Item Analysis Data

WELLS

Internal Consistency 0.75

Standard deviation of Discrimination Index 11.3

ITEM	DISCRIMINATION INDEX
1	86
2	93
3	70
4	75
5	75
6	93

A3.1.3 Item Analysis Data (continued)

PBAR

Internal Consistency	0.77
Standard deviation of Discrimination Index	12.0

ITEM	DISCRIMINATION INDEX
1	95
2	95
3	60
4	88
5	77
6	117

A3.2 MAXB Questionnaire

A3.2.1 Questionnaire Paper

Please reply to statements 1 to 9 by writing a letter in the right hand column. Write the letter

A - if you strongly agree

B - if you agree

C - if you are uncertain

D - if you disagree

E - if you strongly disagree

with the following statements.

	Please write your answer in this column
1 After using the computer simulation I felt that I was happier with Maxwell-Boltzmann statistics than before I used the computer.	
2 After using the simualtion I felt I knew more about the way the distribution changes as the number of particles alters.	

Please write your answer in this column

3 After using the simulation I felt I knew more about how frequency of occurrence of the most probable macrostate varies as the number of particles changes.

4 After using the simulation I felt I knew more about how the most probable macrostate influences the ensemble-averaged distribution.

5 I feel the time spent at the terminal was a productive use of time.

6 If the facilities were available in the future at Study Centres I would use this program.

7 I felt that the computer was in charge.

8 During the work I was more involved in running the computer than in understanding the material.

9 The method of instruction was too inflexible.

10 How long did the interaction take you? ....Minutes

11 Have you used a computer before you came to this Summer School? (Circle your reply)

NO	YES (at OU)	YES (but not at OU)

12 If your answer to Question 11 is yes, did you write the computer program or did you use a computer program already in existence?

....

13 Were there any technical problems with the computer? (e.g. bad phone lines) YES/NO

If YES please specify.......................................

Thank you for answering this questionnaire; if you have any further comments to make will you please do so in the space below.

A3.2.2. Raw Data

Statement/Question	Number of responses						Mean	Std. dev
	2(A) Strongly Agree	1(B) Agree	0(C) Uncertain	-1(D) Disagree	-2(E) Strongly Disagree	TOTAL		
1 After using the computer simulation I felt that I was happier with Maxwell-Boltzmann statistics than before I used the computer.	1	18	15	7	2	43	0.2	0.9
2 After using the simulation I felt I knew more about the way the distribution changes as the number of particles alters.	4	27	7	3	2	43	0.7	0.9
3 After using the simulation I felt I knew more about how the frequency of occurrence of the most probable macrostate varies as the numbers of particles changes	1	22	14	5	1	43	0.4	0.8

A3.2.2. <u>Raw Data</u> (continued)

Statement/Question	Number of responses						Mean	Std. dev
	2(A) Strongly Agree	1(B) Agree	0(C) Uncertain	−1(D) Disagree	−2(E) Strongly Disagree	TOTAL		
4 After using the simulation I felt I knew more about how the most probable macrostate influences the ensemble averaged distribution.	1	14	19	7	2	43	0.1	0.9
5 I felt the time spent at the terminal was a productive use of time	9	17	10	6	1	43	0.6	1.0
6 If the facilities were available in the future at Study Centres I would use this program	8	7	17	10	1	43	0.3	1.1

A3.2.2. Raw Data (continued..)

Statement/Question	Number of responses						Mean	Std. dev
	−2(A) Strongly Agree	−1(B) Agree	0(C) Uncertain	1(D) Disagree	2(E) Strongly Disagree	TOTAL		
7 I felt the computer was in charge	4	7	5	17	11	43	0.5	1.3
8 During the work I was more involved in running the computer than in understanding the material.	5	11	4	19	3	42	0	1.2
9 The method of instruction was too inflexible	4	10	8	15	2	39	0	1.1
10 How long did the interaction take you? (Minutes)						35[21]	37.23	19.8

[21] Several students interpreted this as the time it took for the computer to respond to their input.

A3.2.2. Raw Data (continued....)

Statement/Question	Number of responses				
	No	Yes (at OU)	Yes (Not at OU)	Both (OU + Non OU)	Total
11 Have you used a computer before you came to this Summer School?	2	32	3	4	41

A.3.2.3 Item Analysis Data

Internal consistency	0.73
Standard deviation of Discrimination Index	15.3

ITEM	DISCRIMINATION INDEX
1	102
2	67
3	73
4	47
5	88
6	78
7	33
8	57
9	85

Appendix 4: Student Comments on the Programs

This appendix is a list of the comments students made about the programs.

A.4.1 <u>WELLS and PBAR Student Comments</u>

Week 1

'VDU too slow'

'The VDU was a much better peripheral for displaying and understanding the results of the values inputed'

'The VDU appeared to be very slow.'

'VDU too slow.'

'Tutors not available for advice when required (Bob excepted!)

'Answered after only half-time spent on computer work:-

I may feel differently after the second session.'

Week 2

'The use of the computer was less of an intellectual drain than answering the questionnaire'.

'It is a simple matter to improve the user interface in 'WELLS' <u>even in BASIC</u>

(i) facility to print out nearest eigenvalue with/without graph without having to make a guess first.

(ii) facility to print out nth eigenvalue without having to guess an energy 'not too far away'.

(iii) Elimination of occasional overflow and underflow which aborts program!

(iv) Facility to bypass some of the chatty output and input when one know what one is doing'

'WELLS after eighty minutes we were just getting familiar with the potential of the program. Extra time would have to be much more beneficial'.

The WELLS program is too mechanical. One could tell someone who knew nothing about Q.M. the 'rules of the game' and he could find the eigenvalues. The visual display is perhaps more useful. I did not have long enough on PBAR to give a fair appraisal'.

'Extensive delays were experienced in the evening'.

'Tracing the axes in PBAR seemed a waste of computer and my own time'.

'At the risk of being presumptious, I would like to suggest that you should be cautious in interpreting the results of this enquiry as a guide for the avowed purpose. I do not think that the experiments made any difference whatsoever to my ability to answer the questions correctly when I had to do it.

On the other hand I found, rather to my surprise, that they were interesting and enjoyable to do and I think I learned a lot from them. What we lacked was an adequate briefing in advance, more time to do the experiments and time to think during and afterwards about the implications of the computer's (or system's) response to changes in input. The briefing we had in numerical solutions of differential equations was perfectly good as far as it went, but we would have benefited from being told what, for instance, we should be doing in the narrow case and the sort of decision we should have to take about changing the input and (probably) some guide as to how to take these decisions. Please don't tell me that it is 'all in the book'. It probably is but we had no time to read the book thoroughly here and were positively discouraged from doing so before the course on the grounds that it all be adequately explained when we came to do the experiments.

Incidentally, in case I am misunderstood, the assistance during the experiment by Bob and the Tutors was excellent'.

Week 3

'The subjects of the programs were ones which I had not covered in the units. I spent most of the allocated time studying the relevant units and E which I thought was more a productive use of my time'.

'In house computer might have enabled higher speed response on the terminals. Response too slow for best man-machine interaction'.

Week 4

'Don't understand question 7'.

'Both programs print superfluous information on request.

Add facility to supress output not required'.

'VDU: systematic investigation of effect of variable of great value'.

'A valuable teaching aid'.

A4.2 MAXB Student Comments

Week 1

'Not enough tuition available in human form during the teaching exercise'

'A tutorial would be more useful'

'On feeding identical information into the computer, the second reply (which was considered to be correct by general consensus) was different to the first.'

Week 2

'Sorry about answers 2, 3, 4 but honestly felt more confused after doing the program'

Week 3

'Insufficient time was allowed between running the program and filling in the questionnaires. If there had been more time the program would probably have achieved higher scores'

'MAXB spends too much time in presenting detail in the form of accurate numbers. More graphical presentation should be used'

'If you do not know the definition of the terms involved before you start the program you can't do much, it is not a teaching program as I understand it'

Week 4

'Would it not be possible to programme the computer to answer p.........Questions on the MAXB programme'

'I felt that more assistance from the tutor about the interpretation of the results would have facilitated my understanding of the information presented by the computer'