DESIGNING COMPUTER SOFTWARE THAT TAKES ACCOUNT OF INDIVIDUAL LEARNING STYLES

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ABSTRACT

In this study, an attempt was made to characterise the link between students' learning styles and they way they choose to work through a piece of computer-assisted learning material. It was decided to focus on one aspect of learning style, namely learning motivation: a psychological characteristic possessed by every student that has much influence on the way they prefer to learn. Motivation was an obvious choice, since it is easy to devise a model to describe the way in which the different motivational types map on to styles of working through a teaching program. The model predicts that conscientious and achiever students prefer a type of teaching material that has a strong element of teacher control, whereas the more curious students will prefer an environment that offers more freedom. It is more difficult to predict what preference will be expressed by the socially motivated students in this regard.

To test this model, a group of twenty-five students, mostly undergraduates, worked through a piece of computer-assisted learning (CAL) material that offered them a choice of working modes - one more structured, and the other allowing complete freedom of movement. In the background, the computer kept a log of all activity as the student worked through. The log data was refined to extract information about the route taken and the level of involvement in the various activites offered by the program. In addition, each student's learning style was measured using a questionnaire. In order to evaluate the model, correlation was looked for between each student's learning style and the way they used the program.

The data strongly suggest that learning style does have some effect on the way people chose to work through the program. Almost without exception, the conscientious students worked through the program in the suggested order using the more structured working mode and showed little sign of departure from it. By contrast, those with curious tendencies tended to chose the more open working mode and adopted a more exploratory working style. Thus, although the sample size was relatively small, it would appear that the results support the basic model, though it is also clear that the exact nature of the linkage is quite complex.

Although unanticipated, it seems that a second conclusion could be drawn from the data. A significant difference is also visible between the undergraduates and non-undergraduates in the group with regard to learning and working styles. There seems to be little variation in working and learning styles amongst the undergraduates. It is hypothesised that other factors may be masking the real learning styles of the undergraduates causing them to work in a very conscientious fashion.

There is much scope for further study in this unexplored area of research. The link between learning style, both in terms of motivation and other factors, and preferred working style needs to be clarified further, so that CAL material can be designed to cater for the learning needs of individual students and so enhance the effectiveness of their learning.

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CONTENTS

CHAPTER 1

Overview of the Current Situation

We live in a technological age. Computers have become such a part of everyday life that it is difficult to imagine a world without them. Ever since it became practical to do so, computing technology has been used for educational purposes. As the hardware has become smaller, cheaper and more powerful, computers have steadily become more and more commonplace in education. I hope, by way of the research described in this dissertation, to add to the current understanding on how computers can assist us in the field of education. From recent literature and my own experience as a programmer on a teaching software project, I will attempt, in this chapter, to give a critical overview of the use of computer technology past, present and future in UK Higher Education.

1.1. Computer-Assisted Learning (CAL) Past and Present

1.1.1. A Brief History

There have been initiatives to develop the use of computer technology in higher education ever since it became possible to do so. Since the early Seventies, there have been a series of government-funded initiatives to investigate and develop computer-based approaches in university teaching, beginning in 1974 with the National Development Programme for Computer Assisted Learning [1]. The first phase of the Computers in Teaching Initiative (CTI) began 1985 in response to the Nelson Report. More recently, the Higher Education (HE) funding councils have established the Teaching and Learning Technology Programme (TLTP). TLTP involves the setting up of inter-university collaborative projects between several university departments who share the desire to incorporate computer technology in the teaching of their own subject. Their funding ranges from around £50,000 to £1 million per project over three years. At the time of writing, the first phase of TLTP projects are drawing to a close, and a second phase, which began one year after those in the first phase, is under way.

1.1.2. The Current Situation

The government is pushing for great increases in student intake into Higher Education Institutions (HEIs), with a projected increase in student numbers of 50% by the year 2000, compared with the size of the current student population [1]. At the same time it is seeking to minimize the cost of such an expansion. Clearly, there is strong feeling amongst many, both in the academic world and in the graduate employment field about the rising student numbers and the steady decline in funding. In a newspaper article on October 4th 1995, it was reported that

> "The Association of Graduate Recruiters, which represents 300 major employers, called on the Government to change the method of university funding so that increasing student numbers was no longer more important than quality of teaching." [42]

In a similar article in March this year about cash cuts in university funding, it was reported that

> "UNIVERSITY teaching and research grants will be cut by 11/2 per cent in real terms from September, the Higher Education Funding Council announced yesterday. Dr Kenneth Edwards, chairman of the Committee of Vice-Chancellors and Principals, said this came on top of a 25 per cent cut in overall funding per student over the past five years.
>
> He appealed to Mrs Gillian Shephard, the Education Secretary, to halt the 'continuing downward spiral'. The Association of University Teachers said the reduction would do 'incalculable damage' to the quality of the university system. Students would have fewer books, larger classes and less access to new technology." [43]

The student population is set to become more diverse with respect to individual variations in entry-level qualifications, learning ability and so on. In addition, the demand for higher quality graduates is set to increase further [2]. Consequently, HEIs are forced to devise means of absorbing the effects of these changes without compromising the quality of teaching and learning which they traditionally stand for. The aim of the TLTP initiative, quoted below, reflects this.

> "To make teaching and learning more productive and efficient by harnessing modern technology. This will help institutions to respond effectively to the current substantial increase in student numbers and to promote and maintain the quality of their provision." [2]

There has been an increasing awareness in recent years that the computer might have the potential to alleviate some of the problems associated with HEIs [1]. This would include pressures on staff time, shrinking financial investment by the government, the steadily rising student population as already mentioned, but more than this, to yield new teaching opportunities by offering the means to implement teaching ideas that previously existed only in the imagination, and to open up many fresh possibilities. Yet despite this awareness, it is widely felt that the state-of-the-art technologies that are becoming increasingly commonplace in HEIs have yet to grasp the full potential that they offer as a new and exciting teaching medium [3]. There seems to be broad agreement about the "considerable untapped potential of CBL" [1].

Most of the interest shown in CAL has come from the science, engineering, or mathematics direction. As one lecturer said, it is not immediately clear how CAL could assist in the teaching of some arts subjects e.g. philosophy [2]. This reflects both the nature of the subjects involved and the attitudes to teaching held by lecturing staff. Generally speaking, students of science-based disciplines tend to be taught to find *the* correct answer, to look at a problem and find one solution. By contrast, arts-based subjects tend to encourage a more divergent approach. Here, students are more often encouraged to find a satisfactory solution of their own. Exactly how can a computer supersede a good textbook and tutorials in assisting a student to unravel the complexities of utilitarianism? It is much more obvious how Newton's Laws of Motion can be represented and explored in a computer environment.

The introduction of technology can potentially bring both short-term and long-term benefits. Organisations, including HEIs, are usually quick to perceive the short-term benefits of introducing technology. These include doing current tasks better, increasing productivity and cost effectiveness. In practice, the same organisations tend to introduce technology in such a way as to cause as little disruption as possible to their current strategies [4].

1.1.3. Problems with the Uptake of CAL

Despite all their potential, computers seldom seem to be used in university teaching [5]. What obstacles are in the path of the development of the computer as a tool that enhances the efficiency of teaching on one hand, and the effectiveness of learning on the other? The first of these questions finds its answer in the organisational realm and the second addresses more educational and student-oriented issues. I will deal with student learning issues more fully in the next chapter.

The availability of technology is not the problem. Currently, the UK Higher Education Institutions boast a high student:workstation ratio of around 10:1. This compares favourably with the USA, where the ratio is around 45:1, and with Germany and Japan where the ratio is even lower [6].

One of the problems to date has been the time lag between the development of a computer-based technique and its appearance in actual teaching software [2]. The hypertext system of linking relevant collections of ideas by common linkwords (or 'hotwords') was developed twenty years before it gained enough credibility amongst teaching staff to be offered to students.

There are a host of other problems, however. Hammond et al cite two surveys conducted among academic staff at various HEIs [5]. They were given a questionnaire covering various CAL issues, in which they were asked to identify, in order of importance, the three most important hindrances to their own use of CAL. In both cases, lack of time to investigate and develop CAL was cited as the major problem (almost 80% of respondents in both surveys mentioned this). In many cases, academic staff are aware of the benefits of CAL, but are unable to obtain teaching relief to investigate and develop teaching software. Lack of training, lack of support staff and lack of information also feature highly on each list. It is encouraging that in one survey, 65% of respondents said that they would have liked more time to evaluate the potential of computers in teaching, thereby assessing the needs that a computer might be able to meet. In addition, the failure of universities to recognise involvement in CAL as a factor in the case for promotion of academic staff was also a major disincentive [5].

In my own experience of working with academic staff, the problem is not usually the lack of enthusiasm. It is, amongst other things, the lack of training both in how to exploit the computer fully as a teaching medium (an instructional design issue) and how to decide if the computer is really the best medium for teaching in any particular instance. Ideally, this sort of training for academic staff should have been provided for staff who intended to get involved, along with the cash to provide the teaching relief to allow them to do it.

> "There is never enough cash to equip a decent programme of piloting, dissemination and staff training that would be needed to properly establish an innovation. " [7]

In the same vein, a working party set up to investigate ways of developing the use of CAL in HEIs recommended that

> "... funding be made available for the establishment and evaluation of models for effective courseware within institutions" [1]

It is possible that the onset of more structured approaches to CAL and improved dissemination of relevant information within and between universities will begin to solve some of these problems.

Another major problem is the lack of coordination at all levels - nationwide, between HEIs, and within HEIs themselves. There is no national body to oversee the use of CAL in HEIs. Consequently, there is no commonly agreed set of guidelines that help promote portability between individual machines, within HEIs and between HEIs. The same wheels have been, are being, and will continue to be reinvented over and over again as long as such fragmentation exists. This amounts to duplicated effort on an unprecedented scale, and breeds parochialism in attitudes to software design and production which manifests itself as the famous *Not-Invented-Here* syndrome [**5**]. To put it another way ...

> "Each item of courseware can be thought of as a jigsaw puzzle piece, but unfortunately not only do the pieces not fit together, but they are parts of slightly different pictures." [**6**]

> "Currently-available material has been developed piecemeal" [**1**]

> "... in the CAL area, they [academics] consistently ignore the published literature and continue to reinvent the wheel" [**44**]

The new technologies will only make a lasting difference to the quality of education when they are properly integrated into the existing education system. [**41**].

> "The implementation and resourcing of CBL requires forward planning and management on a national scale - the enthusiastic amateur model has done all it can." [**41**]

1.1.4. The Ideal World

In the search for the ideal infrastructure, however, it is easy to lose sight of what the real aim is. It is all too easy to get caught up with the process of providing CAL that we forget the purpose, that of enhancing the quality of teaching and learning. The subtle process whereby the means gradually becomes the end, a process that can be hard to detect, is, in the words of C.S. Lewis,

> "... the subtlest of all the snares" [**45**]

Before we address organisational issues, we must first try to see the world through the eyes of those who ultimately stand to gain or lose i.e. the students. The *primary* justification for any CAL enterprise, from the adjustments at higher levels of organisation, through the allocation of financial resources by funding bodies, to the design and implementation of teaching software itself must not be, in the first instance, to save money, though necessarily it must. It is to improve the quality of teaching, and in doing so, to enhance students' learning [**7**].

If it can be ascertained exactly how to use this new medium to facilitate learning, then we can work our way back up to the top, where the appropriate level of organisational change can be realised. Although the implementation of new technology in any setting must begin to happen from the top down i.e. the plan is accepted before the money arrives, then the new staff are appointed, then the software is planned and written, then the students are let loose on it, the *thinking* that gave rise to it in the first instance must have begun with a clear insight into what was needed on the ground. In other words, we take the teaching needs to the technology [7].

Thus, the first stage is to ask what we are trying to achieve. This involves some form of detailed study to list the teaching requirements which are outwith the scope of, or are not adequately covered by traditional teaching methods. Then, armed with knowledge about what the computer is able to deliver, an agenda is drawn up - the teaching needs that the computer is able to meet, but more importantly, is *required* to meet because it has first been established that the inability to satisfy these teaching requirements by other means has been detrimental to the learning of the students taking the course.

1.1.5. The Real World

There are different views about what the real situation is. In the view of some, it would seem that the above is not happening and that millions of pounds have been allocated to investigate the use of this new medium with little reference to learning needs [7]. In this scenario, the technology is driving the learning, and not, as it should be, the other way round. According to Laurillard, the blame rests on the funding councils for their funding strategies.

> "Funds are given for the development of materials using a particular medium and the search is on for the learning objective that best fits it. While funding bodies persist in this nonsense, designers are condemned to find a post-hoc rationalisation of what they do." [7]

However, some would claim that this is an inaccurate stance to take, and that the learning and teaching are being put first. In his keynote speech at CAL '93, Colin Campbell reasserted that the title "Teaching and Learning Technology Program" (TLTP) was chosen because it emphasized that the teaching and learning come before the technology.

There is probably some justification for both views. However, I'm sure that no-one could complain that money is being made available, since there will always be a demand for new technologies in education. It is a question, then, of refocusing the available resources. As discussed above, this must come about by reminding ourselves of what the real goals should be.

1.2. The Future of CAL - Two Approaches

There seem to be two distinct camps here. Firstly, those who see computers as a means to *assist* current teaching e.g. lectures, tutorials etc., and secondly, those who see computers as a means of *replacing* either all or some current teaching practices.

1.2.1. Computers to Replace Teaching

This approach can be summed up by MacFarlane et al, who stated in their recent report ...

> "In the long term, changes at the individual student level will be profound. Students will have to be taught how to manage their own learning to an unprecedented degree. They will have to ... self-pace and self-structure their programmes of learning ... to choose from a spectrum of virtual self-instruction under support to group working of various types." [2]

> "The role of the lecture must be reassessed and re-presented in an appropriate free-access format enriched, as relevant, with film and simulation material." [2]

In this view, the traditional lecture, consisting of 50 minutes of expository teaching, or "chalk and talk", could also be put to other purposes. The reading up of recommended texts etc. for each module could be done in allocated study time. It is possible that these teaching materials would be wholly or partly computer-based. In this scheme, the lecture is transformed from an hour of textbook facts (which the students will have covered using these other means) into a forum for summary, review, discussion, elaborating, linking etc. of the ideas contained in the teaching material. Thus, contact time with the students is used to fertilise genuine understanding and not only for the transmission of information.

> "Although lectures and lab classes will continue to play an essential role during the next decade ... consider carefully how all activities currently carried out in groups may be more effectively and appropriately carried out using supportive learning environments." [2]

Other reports take a similar stance, envisaging an advanced form of distance learning, where students are individually equipped with computers, and their residences have labs of workstations which are networked to the university's computer system **[6]**. True enough, the transfer of information between academic institutions via *SuperJANET* and the Internet is currently possible, but a well coordinated inter-university network of the type envisaged is still some way off. Other reports also talk of shifts from lectures to CAL ...

> "... a shift from lectures to CBL (Computer-Based Learning) can enable more students to be taught without more lecture theatres." [6]

It is also clear that some of the proponents of this approach see CAL as much more than a mere supplement to existing teaching methods.

> "Even where CBL in merely a supplement to conventional teaching, it can mitigate the effects of larger classes through the interaction it offers." [6]

In their recent report, MacFarlane *et al* take a similar stance, seeing much of current teaching practice being superseded by technology-based methods. In the section on 'The Benefits the Computer Offers' in chapter 2, I will set out some of the advantages of CAL as seen by MacFarlane *et al.* Many of the benefits they set out will not be felt for many years if ever. They would appear to consider the computer as the answer to almost all teaching needs.

There is some value in envisaging possible future scenarios in this way. There is talk of "internet villages" and "net communities" which already exist to an extent via the ever-expanding Internet. The education community would do well to utilise modern technology where it is deemed appropriate. At the same time, however, it could be said that the more speculative ideas contained in this and similar reports may not work in practice as they would result in computer technology being used to attempt to meet certain student needs that are better dealt with in other ways, and in doing so, give the computer responsibilities beyond its means to discharge. The potential deprivation of much of the student contact with teaching staff and with other students is a worrying consequence of this silicon classroom scenario. As some have said,

> "To ignore the human input or to forget that education has something to do with the exchanges between lively minds is to do the whole process a mischief." [8]

> "As iron sharpens iron, so one man sharpens another" [9]

It is necessary to keep in mind at all times that the computer has, like all other teaching tools, its strengths and weaknesses. Thus, courses that become entirely computer-based may suffer not only from some of the computer's weaknesses as a teaching tool, but they may import other as yet unforeseen problems of their own. On the other hand, something must be done to alleviate the rising pressure.

1.2.2. Computers to Assist Teaching

Most of the TLTP projects I have had dealings with take the other approach, in which the computer is used to *assist* current teaching. Our own consortium creates CAL materials to teach statistics to non-specialists using problems with a statistical element taken from their own subject discipline. The teaching of such students consists mainly of more traditional methods. By contrast, many consortia are producing *courseware* i.e. computer software that is used to teach or allow revision of course material.

Other approaches, often used in science subjects is to supplement lectures with computer-based laboratory sessions e.g. simulations of physics experiments, or problem-based lab sessions. Another approach to which the computer is being put in certain subjects e.g. chemistry, is to create "pre-labs". These are often simulations of experiments which students use to derive their own experimental parameters for use in the real lab experiment. The introduction of software that replaces lectures is slow for reasons already mentioned, some of which are organisational or technical e.g. "the currently-available software isn't suitable", and some of which are pedagogical e.g. "we prefer lectures and tutorials as a teaching medium".

1.3. Summary

In this chapter, I have attempted to summarise the state of CAL in university teaching. The expansion of CAL in recent years in UK HEIs is accompanied by a dramatic rise in the student population and drastic cuts in government funding. It is clear that the current usage of technology in UK HEIs is unsatisfactory. There are many reasons for this. There is a lack of national coordination, leading to much inefficiency. Also, the focus of CAL initiatives is too often on the technology instead of on improving the quality of teaching and learning. For these and other reasons, computer technology has not yet found its proper place in our HEIs.

CHAPTER 2

Overview of Learning Styles and Individual Differences

In chapter 1, I examined the state of CAL in UK HEIs past, present and future, focusing on the potential, the problems and promises that are associated with CAL at institutional level. There has not been much mention of the student yet. Hence, from this wide panoramic view, I will now consider the situation from the standpoint of the students as individuals with individual learning needs.

There has been a great influx of money from funding councils to produce CAL. Despite this, the situation in HEIs regarding CAL is fragmented and disorganised. Given that the money has been allocated, that student numbers will continue to rise, how can we alter current practice to make the best use of current resources? One approach, which is the theme of this research, is to use the computer to deliver a learning experience that is more tailored to individual students' learning needs. In this chapter, I will lay the foundations for my own research by examining some of the ways in which students differ in their approach to learning. Secondly, the strengths and weaknesses of the computer will be discussed in general terms. Thirdly, the interaction of learning styles with various aspects of CAL will be discussed. And finally, I will build on this by speculating how the computer might be used to detect different learning styles as a preliminary step to delivering an individualised learning experience.

2.1. Individual Differences in Learning Style

Why consider individual differences in learning style in the search for a teaching philosophy and practice that will prove the most beneficial for students? Should teaching practice take account of these differences or is there a universal teaching method? In the early years of this century, the issue of individual differences became one of primary concern in educational theory **[10]**. It is commonly held nowadays that the most beneficial teaching interventions are those that make allowances for individual learning styles. Cronbach discusses so-called "aptitudes" which he defines as

> "... a complex of personal characteristics that accounts for an individual's end state after a particular educational treatment i.e. that determines what he learns, how much and how rapidly he learns. This may have as much to do with styles of thought and personality variables than abilities covered in conventional tests." **[10]**

Other researchers state that learner motivation, which will be discussed in more detail later, is a product of the interaction of psychological characteristics intrinsic to the student with the teaching procedure itself [11,12]. It has been said that the study of individual differences is best carried out in the light of knowledge about the processes of learning and performance [13]. Ausubel stated that teachers should take account of individual differences in motivational patterns [14].

Cronbach sets out three ways in which teaching can adapt to cope with individual differences between students. Firstly, the individual differences can be erased ...

> "Most tactics schools use are intended to minimize the nuisance of individual differences so that it can go on teaching the same unaltered goals." [10]

As I discussed in the first chapter, institutions often deal with new ideas by selecting the ones which cause the minimum disruption to current practices [5]. Secondly, teaching and learning goals can be matched to the individual. And thirdly, the teaching method itself can be altered. Again, to quote Cronbach,

> "... the process of adaptation ... calls for a theory whose propositions would state the conditions best for pupils of certain types ..." [10]

In the same vein, Cordell states that both the quality and the durability of learning improves when the teaching strategies employed match the individual's learning style [15]. Laurillard stated that university teachers must know, in addition to their subject, about student learning and what makes it possible [7].

2.1.1. What Students Bring To Learning

No student is a blank sheet. When students come to learn, they bring with them a package of many things - personal characteristics (emotional, psychological etc.); their past experience in learning situations, accumulated knowledge, preconceived ideas and so on. The contents of a student's "personal baggage" will directly affect his learning.

Many studies explore the area of individual student characteristics in a context-free vacuum. Thus they cannot determine how important the psychological factors under consideration are in the learning process [7]. The main problem with the interpretation of this type of study is gauging the extent to which a particular characteristic is fixed for an individual ...

> "The learning process should be viewed holistically i.e. knowledge is situated and contextualised. This sits unhappily with the notion that students might have personality characteristics that determine the way in which they think, irrespective of the context." [7]

It has been suggested that we should view differences in learning style as being available to the student population at large, and avoid making the strong assumption that they can be identified as characteristics of individual students. This view is at odds, as we shall see in the next section, with Adar's theory that one particular individual learner characteristic, motivational style, remains stable throughout different learning contexts [12]. However, Laurillard goes on to say that

> "... there are identifiably different ways of thinking, often linked to the type of subject being studied." [7]

There is also a danger that we pigeonhole students in order to simplify the diversity of the student population. Laurillard continues

> "It is possible to accept that there can be both consistency and variability in students' approaches to learning. The tendency to adopt a certain approach, or to prefer a certain style of learning may be a useful way of describing differences between students. But a more complete explanation would also involve a recognition of the way an individual student's strategy may vary from task to task" [7]

Ramsden has said that although it is clear that the same student uses different approaches on different occasions, it is also true that there do exist general tendencies to adopt certain approaches which are related to the varying demands made by courses and previous educational experience. Thus, variability and consistency coexist [7]. In addition, students' approaches can also be influenced by their perceptions of the kinds of assessment they are likely to face.

Whatever the correct view is, it is clear that students do exhibit a range of cognitive and other individual characteristics, and that the student population at large displays a wide spectrum of learning styles. I will now examine some of these individual differences in more detail.

2.1.2. Motivational Patterns

What makes people want to learn? What is it that motivates individuals to acquire knowledge and understanding in a field that is unknown to them? What factors affect their interaction with new concepts and ideas? In this section I will examine motivational factors that have a bearing on student learning.

2.1.2.1. Defining Motivation

The term "motivation" is frequently used to describe anything from passing interest to a much stronger urge that leads to certain behaviours. Some general theories of motivation describe very general low-level processes that are shared by all living things. At the other extreme there are others that describe specific modes of human behaviour. In this section I will examine some of the approaches that have been taken to studying motivation, but as before, I am working towards principles that have a direct or indirect influence on student learning. In broad terms, a motive can be defined as

> "... a disposition to strive for a certain kind of satisfaction ... as a capacity for satisfaction in the attainment of a certain class of incentives." [16]

2.1.2.2. Theories of Motivation

Although some of the following systems are not related directly to learning, they contain some principles that are quite useful in the search for a working definition of motivation.

The Associative Theory

This is also known broadly as "stimulus-response" (S-R) psychology and employs such terms as "responses", "drive", "need-reduction" and so on. This theory applies in some way to all animals. This theory states that motivation begins with an experienced need. The need, or "stimulus", can be of a physical nature e.g. a need to eat, to avoid danger or of a psychological or of an emotional nature e.g. the need to find out, the need to associate with others etc. This need motivates an appropriate "response" that leads to the reduction of that need e.g. the animal eats, finds cover, or finds out what it wants to know. The consequences of any given response i.e. the experience of pleasure, relief, satisfaction, pain etc. are called "reinforcement" [17]. As we shall see later, there are various psychological needs that a student may possess which directly affect his learning motivation. Skinner coined the term "self-reinforcement" when applying this theory to student learning [17].

The Cognitive Theory

Unlike the association theorists, who emphasise needs (or drives), reinforcement and the control of behaviour by external influences, the cognitive theorists place their emphasis on internal motivating factors. In other words, individuals interpret their environment, and are motivated by curiosity, expectations etc. to set goals and so on. This self-directed view of motivation is also helpful for our working definition of the learning motivation that occurs within the student since it introduces the idea of motivation as an intrinsic learner characteristic **[17]**.

2.1.2.3. The Role of Motivation in Learning

In the late 1950s, the emphasis in this field shifted from need-reduction psychology to intrinsic learning motives such as curiosity, exploration, manipulation etc. as primary drives in their own right. In other words, learning motivation began to be distinguished from the homeostatic drive-reduction mechanisms which are present in all animals **[14]**. More specifically, we are talking about those classes of motivational drive which directly affect the student's desire to learn, which colours his expectations of that learning experience, and which govern which types of learning experience he will gain the greatest benefit from. Regarding the importance of motivational considerations in a teaching context, Ausubel stated that

> "Motivational characteristics are sufficiently important in school learning that they should engage our most serious consideration if we wish to maximize ... classroom learning" **[14]**

According to Anderson and Draper, motivation is generally considered to have the most significant effect on learning of any single factor, though they reckon that the whole question of motivation is poorly understood **[18]**.

2.1.2.4. The Source of Learning Motivation

This brings us to a more specific meaning for the term "motivation". It is not a mere 'interest-arousal', which stems from the nature of the subject matter being taught. It arises from the interaction of the teaching strategies and procedures employed by the teacher with motivational characteristics intrinsic to the student **[11]**. Students' motivational patterns, interests and preferences play a crucial role in the processes of teaching and learning **[19]**.

However, it is often assumed that the motivational qualities of a given instructional procedure are a function of the procedure itself. The idea that increased motivation resulting from the use of any given teaching method might result from the interaction between the method and individual learner characteristics is not often aired [20].

2.1.2.5. Motivational Patterns

The issue of individual learner characteristics was brought to the fore in the late 1960s by Adar, who formulated a system of classification based on certain psychological needs experienced by students in a learning context [12]. This system was based on a study of the relationship between students' motivational patterns and their preference for certain methods of teaching and learning. From this study, she concluded that

> "... the application of different teaching techniques will affect student's motivation only if the method interacts with the student's motivational pattern." [12]

Adar implies that these characteristics are relatively stable in an individual learner, irrespective of the learning context. She also implies that individual learners differ in their preferences for and their responsiveness to any given teaching and learning method. This view is also expressed by Orbach [21]. In her study, Adar described four basic types of student on the basis of their responsiveness to and preference for different motivating actions. These are ...

Motivational Type	Motivated By
Achiever	A need to achieve.
Curious	A need to satisfy his or her curiosity for new knowledge.
Conscientious	A need to discharge a duty.
Social	A need to affiliate with others.

Table 2.1 A description of the different motivational types.

The Achiever Student

Achiever students are motivated by a psychological need to achieve a certain standard of excellence. They love being tested and love scoring highly in these tests. [12,22]. In addition, they are motivated by the potential gains in status that high achievement can provide [22]. They exhibit a distinct preference for learning environments which involve or encourage open competition. Working in these environments tends to lead to enhanced performance [19]. This competitive streak probably means that they hate being held up by class members who are slower to learn than themselves.

Achiever students also exhibit a marked dislike for group-based activities, or any sort of social interaction in their learning. Their attitude to the class is competitive rather than co-operative **[20]**. However, a study by Good and Power states that achiever students (or 'success' students as they call them), are co-operative in class **[23]**. However, this probably involves co-operation with the teacher in answering questions (which the achiever likes) rather than group learning with their peers.

In a recent study, Kempa and Diaz found that three of the most important features of a learning situation for achiever students are discovery learning, the opportunity to pursue one's own enquiry, and formal teaching **[11]**. They suggested in an earlier study that such students should display a preference for expository teaching and learning, with clear teacher-defined goals and regular evaluation of work by the teacher **[20]**. Orbach stated that achiever students experienced most learning motivation when faced with a set of well-defined tasks rather than a more open-ended, problem-solving environment **[21]**.

Despite the strive to succeed, achievers tend to avoid tasks which involve more than a moderate risk, but will select progressively more difficult tasks when they achieve success **[19,21]**. At the same time, they will avoid low-risk tasks since such tasks afford little opportunity for excellence. They like being under both time and psychological pressure to finish tasks. Also, the achiever student likes to show initiative where possible **[21]**.

There seems to be a second type of achiever student whose principal motivation is to avoid failure, or M_{AF} **[12,16,22]**. Where M_{AF} dominates, open competition is unattractive. In a risk-taking environment, in which tasks may not be completed successfully, such individuals tend to set themselves very easy tasks (in which they will probably succeed) or tasks which are too difficult (which they will almost certainly not complete). This way, uncertainty about their eventual success be minimized. M_{AF} is always an inhibitory drive - it says more about what the student is likely to avoid than what he is likely to undertake.

The Conscientious Student

Conscientious students seeks to discharge the sense of duty that they feel in a learning environment - a duty to the institution to perform well, and a duty to themselves to do their best **[12]**. Failure to carry out this duty will lead these students to experience feelings of fear and guilt **[19,21,22]**. However, conscientious students do enjoy the process of learning **[21]**. They are almost compulsive in their efforts to discharge their sense of duty, and are never sure if their duty has been discharged to the required standard.

It is not surprising, then, that this student is most comfortable when being led by the teacher, who is able to provide continual feedback and evaluation of performance.

Since the teacher is so important to this student, it follows that he will prefer an expository style of teaching with clearly-defined learning goals set by the teacher **[22]**. Good and Power refer to these students as "dependent" students, describing them as "clinging vines" and "frequent handraisers who are always seeking teacher support and encouragement" **[23]**. In general, conscientious students are much more teacher-dependent than any of the other types **[19]**.

In their study, Kempa and Diaz noted that the key features in motivating conscientious students to learn were evaluation by the teacher, experimental work with precise instructions, and involvement in group work, whereas work requiring the use of reference books for finding information had a negative effect on their learning motivation **[11]**. Their dislike for work requiring use of reference books follows also, since this type of work requires a measure of independent study i.e. learning outwith the direct control or influence of the teacher. The conscientious student is clearly uncomfortable with this approach. This is also reflected by their preference for dealing in facts and their marked discomfort when presented with areas of doubt **[11]**. They prefer not to engage in trying to resolve conflicting ideas, preferring to deal with ideas as facts in a dogmatic and opinionated fashion, and retain and re-transmit them as such **[21]**.

They feel lost in open-ended learning environments which require departure from the known path into the territory of original thought. Thus, they may be limited to tasks which require more diligence than original thinking. One study found that conscientious students exhibited a preference for group-based learning activities. Perhaps such an environment provides some of the feedback which conscientious students look for **[20]**.

Achiever vs. Conscientious

On the surface, these two types appear to be very similar. Both achiever and conscientious students prefer an expository style of teaching, to have aims and objectives clearly defined by the teacher, and to have regular evaluation and feedback. The key differences between the two types lie in the control of their learning activities, and the means by which feedback is provided **[20]**. The conscientious students prefer to have the learning activities themselves controlled by their teachers, whereas achiever students do not place any great importance on this. Regarding evaluation of their performance, achiever students clearly prefer open competition whereas conscientious students seem to prefer a more individualistic approach. It has been recently suggested that these two types are in fact subtypes of a common motivational type **[24]**.

The Curious Student

Curious students finds themselves highly motivated when presented with opportunities to satisfy their curiosity about what Adar calls 'intellectual objects' [**12**]. They dislike expository teaching, preferring instead an open-ended problem-solving environment that requires creative and lateral thinking in which the end result cannot be easily foreseen [**20,22**]. These students are motivated on the one hand by novelty i.e. situations involving change and surprise, and on the other, by complexity i.e. where there exists incongruity and conflict of information [**12,22**]. Similarly, Orbach stated that novelty and complexity are the two key components of a learning situation that is likely to motivate a curious student to learn [**21**].

Unlike other types, the curious student finds it difficult to live with unresolved doubts and confusion. In such a situation, the curious student sets out to resolve the conflicts and confusion in the stimulus by exploring and manipulating it [**21**]. Curious students are also characterised by their liking for decision-making [**12,21**]. They do not seem to place any great importance in feedback or evaluation by the teacher [**20**].

In the study cited above, Kempa and Diaz found that the crucial factors for arousing learning motivation in curious students were discovery learning, use of reference books for finding information, the opportunity to pursue one's own enquiry, practical work in general, and risk-taking [**11**]. Exposure to experimental work with instructions and formal teaching had the opposite effect, causing a marked reduction in learning motivation in the same group of achiever students. It is clear from these findings that curious students prefer to take an active role in their own learning by seeking out information, and are not inclined to be merely passive 'receptors' of information [**11**]. The authors concluded in the light of these findings that curious students preferred open-ended learning to the type of learning where goals and tasks were set by the teacher.

The Social Student

Social students (also called "Sociable" students [**12,22**], and students with affiliation motivation [**11**]) are motivated principally by a need to affiliate with other students [**11,12,19,23**]. Thus, they thrive in group-learning environments. They learn most effectively from the cross-fertilisation that occurs during such sessions. They are more person than task-oriented [**23**]. The presence of this motivational trait tends to indicate a student who is quite socially-oriented in other areas of life.

The study already mentioned by Kempa and Diaz found that these students exhibited a general dislike of being tested, and that involvement in group work, use of discovery learning and practical work had a positive effect on their learning motivation. By contrast, individual work and formal teaching tended to reduce the learning motivation of these students [11]. It also appears that the stronger the motivation to affiliate with other students, the stronger the preference for group work and the greater the dislike for individual work are. This trend was also found by Orbach [21]. It is also evident that social students strongly dislike being tested [11]. They have a strong dislike for competition and assessment. This could be predicted since social students dislike an open competitive environment where testing is used frequently.

There would appear to be two subtypes within the socially-motivated students. The one already defined is called the 'positive' subtype, and the second is called the 'anxious' subtype. This second subtype is characterised by an extreme anxiety about personal relationships, leading to fear of and withdrawal from them. These students will experience decreased learning motivation when placed in a group-learning environment. They suffer from a lack of self-confidence in general, and this has a detrimental effect on their performance [21].

From one study, this group appears to be the most complex of all the four groups, and as such is the hardest to define clearly [11]. However, this conclusion seems to depend on the range and type of criteria under examination, since Hofstein and Kempa found that the achiever students displayed the greatest number of preferences and dislikes, and the social students the least [20], whereas Kempa and Diaz found the opposite to be true [11] - see the table overleaf.

Instructional procedure	Achiever	Curious	Conscientious	Social
Knowledge Acquisition Mode				
1. Formal Teaching	-	-	+	--
2. Use of reference books for finding information		++	-	
3. Use of discovery learning	+	++		(+)
Working Arrangements				
1. Individual work				--
2. Involvement in group work			(+)	++
Practical Work				
1. Doing practical work		++		(+)
2. Experimental work with instructions		--	++	
Organisation of Teaching				
1. Opportunity to pursue one's own enquiry	+	+		++
Evaluation				
1. Evaluation by the teacher			++	
2. General dislike of being tested				++
Risk-Taking		+		

Table 2.2. Summary of the relationships between students' motivational traits and preferences for instructional procedures (from reference [**11**]) **Key:** Strong preference indicated by '++';'--' denotes the opposite. (+) indicates a moderate preference due to an indirect, rather than a direct relationship between preference and motivational trait.

Combinations of Motivational Traits

Students who fall completely into one motivational type or other probably do not exist [**21**]. At the same time, Kempa and Diaz found in one of their studies that 43% of a group of students had achieved scores placing them in the top quarter of at least one of the four categories. 80% of *these* students fell quite clearly into one of the four motivational categories i.e. 34% of the whole group (see the black area in **Diagram 2.1** overleaf)

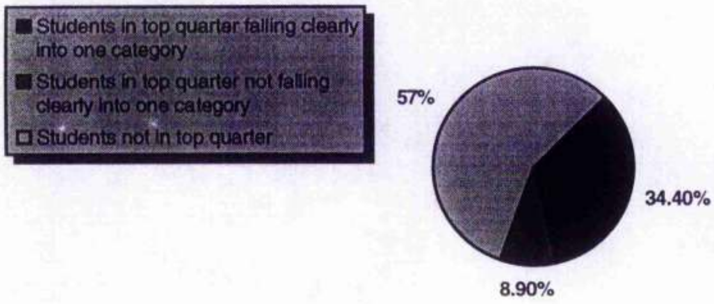


Diagram 2.1. The Percentages of Students Showing a Dominant Learning Style

A further 16% showed mixed patterns in this respect [**25**]. They also found that certain traits were paired quite frequently, namely achiever with conscientious. On the other hand, sociable and achiever are negatively correlated with each other [**25**]. The latter pairing could be predicted from knowledge about the characteristics of the two types - the achiever students preferring competition whereas the sociable students do not work well in this environment. The former pairing follows also, since both conscientious and achiever students share several similarities including a preference for having learning goals set by their teachers [**11**].

2.1.3. Field Independence

2.1.3.1. Background

Let us now consider another characteristic that affects the learning of individual students. Students respond in a variety of ways when they approach a mass of information, or 'stimulus complex', with a view to making sense of it. Within the stimulus complex are various cues that are vital to this process, and others which are irrelevant, or even distracting. It should be noted that the more noticeable, or 'salient' cues are not necessarily the most useful ones when it comes to making sense of the stimulus complex. In fact, obvious cues can often mask the presence of more important, subtle cues. The measure of efficiency with which a student is able to select the most important cues, irrespective of whether or not they are the most salient, is a measure of his field independence. This psychological factor has implications for the way in which students learn and they way in which they should be taught [**26,27**]. I will now discuss field-independence in detail.

2.1.3.2. Defining Field-Dependence and Independence

Field-independence theory concerns the individual's responses to external stimuli. The responses of field-independent individuals (FIs) are governed by internal frames of reference and are not generally affected by social cues, whereas those of field-dependent individuals (FDs) are more influenced by the range of cues external to themselves, namely those cues that exist in their social environment and in the stimulus itself [**27**].

Central to field-independence theory is the hypothesis that individuals tend to be consistent in their approach to different situations e.g. someone who is analytical in one situation will tend to be analytical in others. By contrast, those who perceive globally take the stimulus complex (or 'field') as it is organised *per se* and use external frames of reference e.g. other people, in order to understand it. This was the conclusion that Witkin came to during some studies on field-independence [**28**].

Another central idea is that of self-nonself segregation. The development of a segregated self accompanies the development of internal frames of reference. The availability of these referents and an increasing polarity between self and nonself leads to modes of behaviour which are increasing governed from within. By contrast, the presence of a less well-developed array of internal standards accompanied by a continual reference to others tends to lead to an increasing dependence on external sources to provide guidelines for behaviour [**28**].

2.1.3.3. Field-Independence, Learning and Memory

Field-independence is related to learning and memory. FIs are inclined to employ participative approaches towards learning, whereas FDs tend to adopt the role of a spectator. Field-independence is related to the frequency of dream recall, and also to performance under intrinsic motivation conditions. However, field-independence has very little to do with memory span [**26**]. FIs are more competent at cognitive restructuring (CR) i.e. the range of mental processes involving analysing, reorganising and structuring a stimulus complex. According to Davis and Frank, both CR and interpersonal competency are key determinants of the differences in performance of FIs and FDs in learning and memory tasks [**27**].

Field-independence has been related to learning and memory in several areas. I will deal with some of these now.

Cue Salience and Concept Learning

When faced with a stimulus complex, FIs are able to sample more widely from the cues presented, sampling from among the salient (i.e. noticeable) and non-salient (i.e. indistinct) cues to determine which cues are relevant to the definition of the concept. By contrast, the FDs are dominated by the most salient cues in a stimulus complex. Thus, they tend to accept the organisation of the field as given i.e. the organisation that is suggested by the arrangement of the salient cues [**26**]. However, if the salient cues happen to be the relevant ones, reliance on them will obviously lead to a more rapid attainment of the correct concept.

These phenomena can be observed using Concept Attainment problems in which subjects are asked to distinguish between exemplars and non-exemplars of a class of stimuli. As these are presented, the subject will begin to form hypotheses about the definition of the class concept. Since this process can be observed, it can be determined whether the individual is spontaneously engaging in hypothesis testing. Subjects can be forced to engage in hypothesis testing - it is possible to examine each hypothesis as it is adopted and then discarded in the search for the concept definition. The stimuli used in these tests are composed of many attributes. Thus the attainment of the correct concept requires component analysis i.e. the breaking down of a stimulus complex into its component stimuli. This activity that is more highly developed in FIs [**26**]. As would be expected, FDs are dominated by the salient cues and tend to ignore non-salient cues in constructing hypotheses about the concept definition.

The card game Eleusis [**46**] requires the same kind of thinking as these Concept Attainment problems. In the game, the pack of 52 cards is dealt to 4 people, one of whom is chosen to devise a "rule". The players then take it in turns to play cards onto the table. As they do so, the rule maker informs them whether the played card fits the rule or not. The game proceeds until one of the other players guesses the rule or the cards run out. The rule can be straightforward e.g. "Play a card of different colour to the previous card", "Play a card of the same value or the same suit as the previous card" etc. or more complicated e.g. "If the sum of the values of the previous two cards is even, play a red card, otherwise play a black card". The analogy is obvious. The rule represents the class concept and the card represent exemplars and non-exemplars of the class concept. It would therefore be predicted that field-independent individuals would arrive at the correct rule more quickly, though clearly, an ability to think creatively would be advantageous also.

The Approach to Learning Material

FIs tend to adopt active approaches to learning involving e.g. hypothesis testing. They are not content to learn passively. FDs, however, will tend to make sense of the same situation using a more intuitive, abstractive and passive approach. Generally, FDs take the material as presented (i.e. accept the organisation of the stimulus field as presented) [**19,26**].

FIs may employ associative learning methods i.e. they may use mnemonics and reorganise material for more effective storage and retrieval. Reorganisation reduces interference (caused by the presence of irrelevant information) by creating a conceptual structure that is less 'ragged' i.e. easier to hold intact in the mind and is thus simpler to store and recall. This may involve seeking patterns within the stimulus complex as a framework for reorganisation. Using these techniques, FIs are less susceptible to interference and are therefore less likely to forget information [**26**]. Also, FIs prefer to learn general principles rather than specific instances of these principles. This is reflected in the greater ease with which they derive generalisations.

Social-Interpersonal Sensitivity

FDs are more socially-oriented than FIs, and thus acquire more social information than FIs. Thus, social stimuli will tend to reinforce the learning of FDs and make it easier to recall information. FIs on the other hand pay less attention to social cues unless their attention is drawn to them specifically [**19**]. As already discussed, FDs are more susceptible to external influences and reinforcers, whereas FIs are governed more by internal standards [**28**]. FDs are more efficient at recalling faces of people they have encountered socially, whereas FIs perform better in tests involving the intentional memorisation of faces and names. However, because of their greater social awareness, FDs' performance is affected more by interference from irrelevant social cues. Also, it turns out that FIs are better at the incidental learning of non-social stimuli [**26**].

It is worth pointing out that FIs and FDs only differ with respect to certain types of social interaction. In a situation where there is no ambiguity of information, there is little difference in the way that FDs and FIs behave. However, when there is ambiguity, the FDs will, as already discussed, rely on others as they attempt to resolve the ambiguity, whereas the FIs will turn inwards in the search for a solution. There appears to be little difference between FDs and FIs with regard to attention seeking, response to extrinsic reinforcement, approval seeking or emotional attachment [**28**].

2.1.3.4. Field-Independence and Performance

There is disagreement as to whether field-independence can be used to predict an individual's level of performance. Goodenough postulated that FIs and FDs differ in the *processes* but not the *effectiveness* of learning and memory. It has also been hypothesized that FIs are more advanced developmentally than FDs, and that the different processes of learning and memory employed by FIs and FDs will, under some circumstances, lead to a measurable difference in performance between them.

Concept Attainment problems, as mentioned already, allow comparison of the mental process employed by FIs and FDs. FIs performed better in most studies. Why, then, do FDs exhibit a lower performance? As already discussed, FDs don't rearrange the stimulus field and are thus more prone to be dominated by the most salient cues in it. Furthermore, FDs adopt a more passive approach to learning. It is also possible that FDs find the process of combinatorial analysis (the process of systematically generating all possible combinations and permutations of a set of elements) more difficult. Also, FIs are more efficient at testing hypotheses about a stimulus complex than FDs perhaps because they are more efficient at processing negative information [**26,28**].

Most of the concept-learning studies do not support Goodenough's ideas concerning the relative performances of FDs and FIs. However, the performance of an FI or FD in attaining any given goal will depend on the type of goal it is i.e. performance may be equal if cognitive restructuring does not contribute towards the attainment of the goal. As Witkin points out, field-independence or field-dependence...

> "... represent techniques for moving towards a goal, rather than competence in achieving goals" [**28**]

2.1.3.5. Field-Independence and Short-Term Memory

According to Goodenough [**26**], there is little difference between FDs and FIs regarding their performance in rote learning. However, more recent evidence suggest that this may not be so [**27**]. Differences in performance have been found between them when taking e.g. the seven-digit auditory span test, which tests both the capacity to retain and manipulate information stored in the short-term memory (or M-Space). It is not clear if FDs perform less well because they employ less efficient strategies, or if they fail to take full advantage of their M-space processing capacity.

According to Pascual-Leone, cognitive processing occurs in M-Space [**27**]. He states that field-independent ability is a developmental characteristic and that those possessing this faculty tend to be high M-processors. FDs tend by the same token to be low M-processors. Working space capacity and usage becomes a crucial factor in the effectiveness of learning when a large amount of information is being processed [**19**]. Also, FIs tend to perform better in problem-solving situations which require the individual to use familiar objects in new ways. The cues that were previously useful may become irrelevant in deriving the new concept. Thus, FIs, with their reorganising and recombining abilities already discussed, are in a better position to make sense of this type of problem [**19**].

2.2. The Computer as a Teaching Tool

In the last chapter I examined some of the more general issues that surround the use of computers in HE. So what is it about computers that sets them up as ideal instruments to release some of the pressures of expansion in HEIs? In this section, I will consider their strengths and weaknesses and the interaction of these with student learning styles.

2.2.1. The Benefits Offered and the Drawbacks Suffered by Computers

2.2.1.1. The Benefits the Computer Offers

It is well known that computers work at great speed to perform numerical calculations, draw colourful graphics, store vast amounts of information and that they can present it in a variety of ways.

Not only can information be processed at high speed and be presented attractively, but the computer can create environments that the user can *interact* with. [**29**]. Users are given the opportunity to manipulate the environment that is presented to them. For instance, a student is shown a diagram of the inside of a nuclear reactor. They could be asked to move the fuel rods up or down, alter the coolant pressure, then observe the immediate effects of these changes in real time. The computer can be programmed to offer helpful feedback e.g. for actions that will lead to meltdown of the reactor [**30**]. I will discuss interactivity in detail later.

These and similar approaches, which promote meaningful learning by discovery and problem solving are easy to set up on the computer, and the strengths of the computer are exploited in the process. Notice the emphasis on learning. In an educational context, all deliberations about the capabilities of new media must be judged in terms of the advantages they offer teaching and learning. A more general study of this kind without such considerations is of little use.

In addition, the computer provides the means to adapt the learning experience to the learning needs of individual students [**29**]. This principle is employed in individualised learning, and I will deal with it more fully later.

MacFarlane sets out two types of potential benefit of using CAL [**2**]. The *effectiveness* benefits are those enjoyed by the student learners. The *efficiency* benefits are those that are enjoyed at organisational and teaching level. The effectiveness benefits set out in this report include

- Increased quality of graduate due to better access to information that is more manipulable, more motivating and better tailored to individual learning needs.

- Enriched deeper learning experiences via multimedia and other interactive knowledge environments which provide immediate feedback.

- Simulation of dangerous, time-consuming and complex processes.

- Fast access to and greater availability of subject matter due to CAL's large storage and fast access capabilities.

The efficiency benefits set out in this report include ...

- Increased student turnover because of increased time efficiency - flexible, self-paced learning with immediate feedback etc.

- Reduced failure rates.

- Reduced cost of producing learning resources that will be shared across HEIs and used widely.

2.2.1.2. The Drawbacks the Computer Suffers

This type of consideration unfortunately seems to evade many designers and developers as they set about designing and implementing teaching software. I say this in response to some of the teaching software I come across as a CAL developer. There are many technical problems that have to be overcome e.g. development time, incompatibility between different computers etc., but I am going to look at some of the disadvantages that directly affect the user.

While most teaching software will contain some text, it is well recognised that it is more comfortable to read text from a piece of paper than from a computer screen. I was informed by a psychologist that it takes 30% longer to read text from a computer screen than it does to read it from a printed page. There exists too much supposed "teaching" software which fails to take account of this. Some software seems to consist of screens of text and little else. Other software contains graphics and text, but little interaction. This sort of approach is much better served on paper. There is one questions that must always be asked. "Does this design I have produced really exploit the computer, or is it better on paper or in some other medium?".

There is also the danger that courses that become too computer-based will cause the students to suffer from isolation, both from fellow students and their teachers. The physical isolation of working alone in front of a workstation (even in a computer lab full of students), and the intellectual and social isolation resulting from the lack of human contact could, for many students, be harmful. Most students benefit in some way from interaction with others, even if such interactions do not necessarily contribute directly to their learning. The "hidden curriculum" of these interpersonal relations is a vital part of the whole educational process. As an Open University student commented on television recently, the group tutorials formed a vital part of the course, promoting social interaction among students who normally learned on their own, as well as the chance to exchange ideas on the coursework.

Research into educational psychology concludes that each individual possesses a certain capacity for the short-term storage and processing of information. As already discussed, this is called "working space" or M-Space [**19**]. The research also makes clear that working space capacity varies between individuals, but is always limited. There is clearly a danger that the computer learning environment is so cluttered with colour, sound, graphics and so on that the student's working space capacity is exceeded. This information overload is more likely to occur when the material is new to the student, and will probably lead to confusion and anxiety, thus impairing learning effectiveness [**31**].

2.3. The Interaction of Students with the Computer

2.3.1. General Student Reactions to CAL

Some student trials were conducted using some of the computer software designed by the consortium I work in. I include here a digest of the kinds of reactions that came back. The students involved were studying on various life science courses at Glasgow University, and on this occasion, they worked through software designed to teach them some statistical principles relevant to their degree subject.

The software was not courseware i.e. it wasn't designed as a replacement for lectures and didn't contain lecture-type material (although the statistical course they were on was lecture-based). Instead, it presented problem-solving situations using real datasets which were relevant to the students' degree subject.

2.3.1.1. General Positive Reactions

On the whole, the comments received were very positive. In general, most students found the software easy to use and easy to understand. Many students liked the opportunities the program had offered them to get involved, by entering their own data, or by manipulating the program in some other way. The use of graphical displays was also generally well-received.

Many also mentioned that they had found the clear feedback given in response to their answers very helpful, particularly when incorrect answers had been entered. One consequence of this was that they didn't feel embarrassed about incorrect answers they had entered. In one of the presentations, almost every student found the opportunity given by the program to refresh his or her memory about key statistical concepts very helpful. It was quite often mentioned that working through the software had served to highlight how much work they needed to do for their exams. Almost without exception, the students said that they would welcome this type of presentation as part of their course.

2.3.1.2. General Negative Reactions

Very few of the students cited any disadvantages. A few students found the software too time-consuming for the amount learned. Some students found that they lost sight of what they were trying to learn because there was too much text on screen. Some of the negative reactions are incidental factors that could be ironed out e.g. too little time to finish the problem (could schedule a longer lab session), difficulties using the computer i.e. lack of mouse skills etc.

2.3.1.3. Advantages and Disadvantages over Lectures

The advantage most frequently cited ir this regard was the opportunity the program offered them to work at their own pace. Although self-paced learning is a feature of other teaching methods besides CAL, it is possible that the students were particularly impressed by this feature because it was their first exposure to teaching methods that allowed them this flexibility. Several positive comments were made about the facility offered to move backwards as well as forwards through the material in order to review what had been already covered.

Generally, they found it more interesting than lectures. However, a few responses included comments about the software not covering anything done in lectures. This is interesting since the material presented was intended to supplement lectures and not replace them. Perhaps this should have been more clearly communicated to the students. By contrast, others felt the software had reinforced material covered in lectures.

Again, the opportunity to interact with the program at various points went down well. Various students said that this helped them to understand some of the more mathematical concepts being taught. In general this type of activity made the use of the program more interesting.

Some students said they found the computer-based approach much simpler. Others said they would have been equally happy if the material had been on paper.

2.3.2. Interactivity

In the last section, I examined in general terms the interactivity that computers offer. Let us now look at the issue of interactivity in more detail and then relate it to individual learning styles.

2.3.2.1. Defining Interactivity

Firstly, what is interactivity ? In general, "interactivity" is a term that is used often but seldom defined [**32**]. In my own experience, the term has been used loosely for what turned out to be mere page-turning, and on the other hand for something representing a much more substantial student involvement in the teaching software.

The definition offered by Merrill et al begins with a discussion of "transactions". A transaction is

> "a particular instructional interaction with a student. A transaction is characterised as a mutual, dynamic, real-time give-and-take between the instructional system and the student in which there is exchange of information. Transactions include the entire range of instructional interactions including one-way transactions e.g. lectures, video, documents etc." [**32**]

In his article on interactivity, Bartolomé mentions some comments made by others on the issue e.g. the statement by Johanssen that

> "The point is that interactive lessons require at least the appearance of two-way communication" [**33**]

and the comment made by Anandam, stressing the role of the student in this process that ...

> "... it [interactivity] changes the student from passive observer to active participant" [**33**]

According to Bartolomé, the term "interactivity" is used to convey the fact that both sides of the communication channel i.e. the student and the computer, participate in the transmission of messages, information etc. which are received and dealt with at the other "end" of the channel, and that by doing so, some sort of dialogue develops. Lippmans at the Massachusetts Institute of Technology defines interactivity as

> "a mutual and simultaneous activity of partners" [**32**].

The level of interactivity exhibited by a package can also be thought of as the amount of control the learner has over the presentation of information within the package.

It could be argued that all learning is interactive. Even when a student is engaging in "passive" learning, he is still remembering, comparing etc. and carrying out a range of other mental processes in response to the receipt of information. According to Jaspers, the question is not "interactive or not ?", but "how interactive?" [**32**]. It should be pointed out that the computer can interpret student input and respond to it in ways which are governed by a variety of systems from sophisticated intelligent systems down to much simpler rigid control programs. However, it is important to note that both systems can generate an authentic interactive environment i.e. it's all the same to the student.

2.3.2.2. Levels of Interactivity

Both Jaspers and Bartolomé devise schemes to describe the various levels of interactivity, with particular focus on the role of the student. A outline of these is as follows. Firstly, Jaspers' scheme.

- **Linear Media**

  The student receives a stream of information over whose content and sequence they have no control. Student activity is minimal.

- **Feedback Media**

  In addition to receiving information, the student is given questions and assigmnents. The medium responds to the student's input with feedback. This is characteristic of branching programmed learning. (e.g. tutorial CAL - book with test pages and answer pages)

- **Adaptive Media**

  In response to the reactions and performance given by the student, the medium determines the objective, the route, and the difficulty level.

- **Communicative Instruments**

  As well as being able to react, the student is given the opportunity to enter questions, decisions, problems and information into the medium's system. The medium responds in a number of ways e.g. by answering, showing a solution or consequences, by incorporating the student input into its database.

Bartolomé's system coincides with Jaspers' until it reaches the higher levels.

- **Level 0**

  Same as Linear Media

- **Level 1**

  Same as Feedback Media

- **Level 2**

  The student selects what information he receives next. There are three sublevels - The student chooses from a limited number of options; the student can choose anything, but receives guidance by the author; the student can choose anything - no guidance offered. This differs from Jaspers' "Adaptive Media" level in which it is ultimately the medium which chooses the route etc.

- **Level 3**

  The student not only selects what information he receives next, but can also determine the manner in which it is displayed. This may include a short video, a series of images with accompanying text etc.

- **Level 4**

  The same as level 3 except that the student can also determine the source of the information. Thus they have access to databases of various kinds which may store anything from text to graphics and video sequences.

2.3.3. Interaction of Learning Styles and the Computer

Earlier in this chapter, I examined some of the ways in which students learning styles differ. So then, how can we maximize the effectiveness of learning for students possessing these characteristics? To answer this question, we must look at the computer and the student in parallel to see how the computer can be used to deliver an individualised learning experience.

There has not been much research into the interaction of learning styles with various computer-based teaching strategies. This was also found by Burwell [**34**] and Cordell [**16**]. The few papers I did find seem to utilise different systems of classifying individual learner differences, so it is difficult to relate the work of one group to that of another. The work that has been done centres mainly on the interaction of CAL with various aspects of individual cognitive factors e.g. field-independence, or Kolb's learning styles inventory. I have found no literature on the effect of students' motivational styles on their interaction with CAL.

2.3.3.1. Learning Style and Interactivity

In the last section, I examined the interactivity offered by the computer in detail. This brings us to the next question. What is the ideal level of interactivity? Is one level more suitable than the other? Are different levels more suited to students exhibiting certain learner characteristics? Bartolomé carried out a study into how students with different learning styles perceived video programs with regard to their levels of interactivity. Two version of the same interactive video software were produced, differing only in the extent to which the computer controlled the sequence of information presented. One version controlled the students' actions at all times, whereas the second gave complete freedom of choice about what information to view. It was predicted that the version giving complete freedom would be the better liked by the students [**33**].

However, this turned out not to be the case. This may have been because the subject matter was, by and large, new to the students. A certain level of advance knowledge of the subject is necessary if the student is to know which information to demand. Thus, an unguided approach may not be suitable for students approaching a subject for the first time. No significant difference was detected in the way in which student with different cognitive styles perceived the program. They also found that the students were sufficiently interested in the presentation that the lack of choice in one of the programs did not detract from their enjoyment.

Bartolomé suggests a model for the use of interactivity with students. He proposes that teaching begins with lower levels of interactivity so that the student can concentrate on the content of the program. As experience increases, the level of interactivity should be increased, from the presentation of limited options to an eventual state in which the learner takes total control of the learning environment [**33**].

In a study by Carrier et al cited by Burwell, field-independent and field-dependent children were given the opportunity to select various instructional options in a computer-based lesson. Two treatments were used - the "core" lesson only, or the core lesson with all options available. These options included definitions of concepts, additional expository examples, extra practice items and feedback. The authors predicted that since field-independent individuals are more assertive in their learning, that they would take advantage of the options offered. In doing so they would learn more than the more passive field-dependent individuals and that the field-dependent subjects would outperform the field-independent subjects in the "core only "option. However, it turned out that the field-independent students performed better in both treatments [**34**].

In a study by Stanton and Stammers, trainees were presented on the one hand with highly-structured teaching modules whose format they could not influence, and on the other with unstructured modules in which they could determine the sequence in which they tackled instructional and practice phases. It was hypothesized that the freedom of movement offered by the second approach would lead to more effective learning.

The researchers also examined the trainees' ability to manage the unstructured environment, which was considered to be related to their individual learning style. However, their conclusions were quite vague, though they did report that some subjects had made comments about the lack of structure in the unstructured modules. They also suggest that the subject's ability to manage the unstructured environment may relate to how clearly they can relate the learning goals to that environment [**29**].

In a study of the interaction of learning styles with teaching software with different navigational structures, Cordell prepared two lessons in weight management, one of which had a linear structure and allowed the student no freedom to alter the sequence of learning [**16**]. The second lesson was given a branched structure in which no particular ordering of information presentation was imposed at all. The scheme of cognitive styles chosen for the study was the 4MAT Learning Styles Inventory devised by Kolb as shown below [**47**].

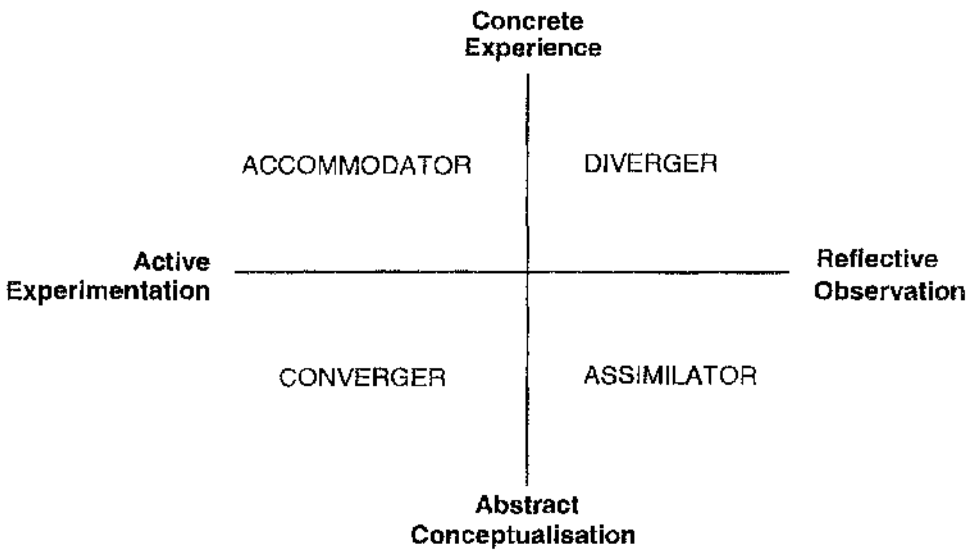


Diagram 2.2. Kolb's 4MAT Learning Styles Inventory

It turns out that the two types that lie at the "Reflective Observation" end i.e. Diverger and Assimilator, performed better, though not significantly so with the branching presentation, whereas the Accommodators and Divergers performed better with the linear approach.

In their paper, Stanton and Stammers discuss the learning opportunities offered by hypertext, which they define as

> "... the idea that knowledge (in the form of text or graphics) may be linked in many ways, providing no formal structure, allowing the individual to explore the knowledge domain at will." [**29**]

· They state that the use of hypertext may have certain advantages over more structured learning environments. However, they seem to imply that hypertext suits all learners by dint of the control it offers the student over the content and sequence of their learning. However, this may not be so. As has been discussed already, certain students, conscientious students for example, may find this freedom leads to anxiety since they display a distinct preference for control of their learning to be in the hands of their teachers. Smith states that instructional materials should present information in varied forms related to learner preference i.e. highly structured or unstructured [**30**]. It will probably be found that most teaching methods provide more learning motivation for some types of student than others. Therefore, teaching that offers more than one approach will probably maximize the learning effectiveness for a greater number of students. It is for this reason that I am looking into ways in which the computer can provide an individualised learning environment for students.

Is there a correlation between certain intrinsic learner characteristics and preference for certain modes of navigation? It is known that some students learn most effectively when they are allowed to set the pace, style and sequence of their own learning. Other students, however, prefer to have certain decisions e.g. the path through the material made for them by others [**34**].

2.3.3.2. Intelligent CAL - Adapting to the Learner

There has been much work recently on devising tutoring systems that can adapt to individual learners. Among these are Intelligent Tutoring Systems (ITS) [**35**], and Intelligent CAL (ICAL) [**36**]. The success of such systems i.e. the extent to which it promotes genuine understanding in the learner, must take account of several factors. Firstly, it must build on current research into the ways in which people learn. Secondly, it must take account of the research in the ways in which different teaching strategies benefit different kinds of student. Only by taking account of these and other factors will produce a system which comes close to being a teaching aid that enhances the effectiveness of learning.

ITS and ICAL are, at least in theory, quite well specified and self-contained systems. However, till now, they seem to have contributed more to the field of artificial intelligence than to education [**7**]. These systems embody certain more general principles - those concerning the adaptation of the learning experience to the individual learner. I would like to consider more specific ways in which the computer can be used to individualise learning. As has been said in the past,

> "The main advantage of the computer as a way of learning is that it allows us to make learning interactive for all students. We can then pay attention to the needs of each student by individualising the learning experience" [**37**]

Let me return briefly to the results of the trials of statistical teaching software by Glasgow University students. I noticed certain comments that appeared on the evaluation forms and wondered if, in the light of some of the research in learning styles already discussed, that they were indicative of certain learning preferences. For example, several students mentioned that the software "led you through step by step", "allowed step by step progress", or that "nothing is better than a lecturer teaching you". I suspect (with a large margin of error) that in terms of motivational pattern, as discussed earlier, these students are likely to be conscientious students since such students display a distinct preference for being led by their teacher, or in this case, the computer.

By contrast, comments such as "more practical than lectures" may indicate a different type of student again. This type of student, unlike those who prefer step-by-step approaches etc. is probably more of an explorer - possibly a curious student. I am not, at this stage, attempting to draw hard conclusions from soft data. However, it is undeniable that the comments the students made are likely to reflect some of the individual differences that exist with regard to motivation and other learner characteristics.

2.3.4. Where Do We Go From Here ?

I have examined some of differences in learning style that exist between students. The computer, as a teaching tool, and as a learning environment has also been discussed. I have also explored some of the ways in which these two areas interact.

So comes the first big question. It has been established that computer software can be designed to promote beneficial learning for different types of student. Can we take a leap from here to program the computer to detect certain learning styles from the way an individual interacts with it? What patterns of inputs can be taken to indicate a particular cognitive, motivational or other learner characteristic?

To begin answering this question, we have to do three things. Firstly, a list must be drawn up of all the possible actions and inputs a student can make during the use of the computer. This will include, if appropriate, i.e. the location, timing etc. of mouse clicks, various keyboard inputs and so on. Secondly, a choice must be made about which learner characteristics we want the computer to detect. Thirdly, and most difficult of the three, we try to map certain inputs and patterns of inputs onto the learner characteristics.

2.3.4.1. Input Patterns

The answer to the first question, as already suggested, depends largely on the nature of the environment that the student is presented with. Nowadays, there is a wide choice of authoring tools that allow the construction of (usually) mouse-driven presentations. The software produced by the consortium I work for is of this type. The location of the mouse clicks is important. At any moment the screen is usually a mixture of static elements e.g. pictures, explanatory text etc. and interactive elements e.g. option "buttons" that offer choice of, for example, what information to view next and so on. These interactive elements are almost always activated by mouse clicks. Also important is the timing and frequency of these clicks.

2.3.4.2. The Learner Characteristic

In my own research I am particularly interested in the motivational aspects of the differences between individual learners and the ways in which the possession of the different motivational tendencies will affect the student's behaviour at the computer. It is also probable that other factors such as field-independence, or other cognitive factors such as convergence and divergence (which I have chosen not to deal with) are responsible for some of the variability in students' interactions with CAL.

2.3.4.3. The Mapping of Inputs onto Learner Characteristics

This is the most difficult stage. There are a multitude of reasons why a student might be spending a long time on one particular screen. For example, they may be taking time to absorb the information it contains, or they might be confused, or bored, or talking to their neighbour. Frequent clicking may indicate superficial involvement, or rapid assimilation of information. However, it is also possible that these input patterns may very roughly indicate that the student lies towards one or other extreme regarding one of the learner characteristics under investigation. The bandwidth is very wide and there is a lot of noise in the measurements by dint of the multiplicity of alternative explanations for the manifestation of any given pattern. But it might just appear from the blur of experimental noise that certain patterns are correlated to whatever degree with certain learner characteristics (which would have to be determined in other ways). It is probably true that any one factor does not offer much resolution on its own, but it would hopefully make some contribution to understanding the situation when viewed alongside factors.

For the purposes of detecting learner characteristics, it is probably not enough to record the location, timing etc. of mouse-clicks in any old presentation. There would simply too much noise. The craft lies in the design of a presentation that appears to be a normal teaching program, and has sufficient content to function as a teaching program, but which has test questions or other activities requiring student feedback woven into its fabric in such a way as to avoid suspicion that the presentation is a test. These questions will have been carefully chosen for their effectiveness in discriminating between students of one type or another. The better the discriminating influence of a particular question, the more it will contribute to a clearer picture at the end of the study. The purpose of camouflaging these special questions is that by disguising the fact that the program is in fact a psychological test, the normal biases that human beings introduce when they know they are being tested can be circumvented. Thus, the level of noise that normally accompanies conclusions drawn from soft data can hopefully be reduced.

2.4. Summary

Research suggests that learning is most effective when teaching strategies take account of differences in learning style between individual learners. It has been shown that students display a range of motivation patterns which affect the way they approach their learning and the types of learning situation they benefit most from. Students also differ in the way in which they respond to external stimuli. Some are better at getting to the heart of the matter while others are less able to sift for the important ideas. This directly affects the way in which they try to make sense of new information.

The computer, as a teaching tool, offers several benefits and suffers several drawbacks. If computers are to be effective teaching tools, teaching methods that use them must take account of individual differences in learning style. To this end it can present interactive environments in which the student can make decisions about what to learn and the order in which to learn it. Another of the computer's great benefits is the opportunity it offers to deliver an individualised learning experience for students with different learning styles. Finally, the computer may be able to detect the student user's learning style and thus present to the student an environment that is tailored to their own learning needs.

CHAPTER 3

Description of Experimental Methods

In this chapter I will describe the experiment carried out to investigate the links between learning style and preferred working style.

3.1. The Idea Behind the Experiment

The ultimate goal of this research project and others like it is to lead to better practice in the CAL field. When it comes to designing material of this type, there is a perceived need amongst many in higher education to take much more consideration of how people learn, particularly with the recent explosion of CAL initiatives in UK higher education.

My original goal was to develop a system which would allow a piece of teaching software to adapt in real time to individual students' learning style as they worked through it. It became clear that that was a very ambitious goal to undertake in the time available, so I decided instead to attempt to establish some basic principles on which a system of this type would be developed. In a system which adapts to student's input, there is in a sense a two-way conversation in which the computer and the student both respond to each other. This is the definition of "interactive" discussed in the last chapter.

The teaching program developed for this study is interactive, though the computer only responds to a limited extent to the student's input. But this does not affect the basic premise that learning style affects working style. For the computer to be programmed to respond appropriately to a certain pattern of student inputs, there must first be a reasonably-well established understanding of what working style is most preferred by, and therefore most beneficial for students with different learning styles. As discussed in previous chapters, when someone is allowed to learn in his or her own preferred way, the resulting learning is likely to be more profound and durable than it would be otherwise. This research, then, seeks to shed some light on this, in the hope that the data generated will eventually allow good adaptive systems to be created.

Specifically, it seemed to make sense to try and uncover links between a student's learning or motivational style and the way he chose to approach the software. If there turn out to be links i.e. if certain assumptions could be made about the student's learning style based on the approach taken, then the computer could then proceed to tailor its presentation according to that perceived learning style.

So then, the specific goal of my research is to look for such links. This goal can be expressed as a series of progressively more specific questions. Firstly, would people work through a computer program in different ways? Secondly, if there are real differences, are they anything to do with the individual's learning style ? I will deal with these in turn now.

3.1.1. How Do People Work Through the Program ?

At this stage, I am concerned to find out simply if there are differences in the way that individuals choose to work through the program.

If there are no real differences in the way people operate in this environment, then it could mean one of several things. It could mean that the computer program is imposing some kind of common working style on all users because of poor design or an inflexible structure. It might also mean that some factors external to the program are causing individuals to work in a certain way. It might also suggest that all human beings share a common learning style. Much research, and our human instincts indicate that this is not a viable alternative. In the long run, we want to identify those factors which differ between individuals and those that are reasonably constant.

So, to answer this first question, I needed to create a working environment and allow people to get inside it and move around. To this end, I constructed a piece of computer-based teaching software. The program was a short teaching module on random sampling in the context of biological sterility testing (checking a batch of ampoules of vaccine for microbial contamination). In order to study the way people worked, it was vital that I kept a log of the users' activities as they used the software.

I predicted that if any differences would appear that they would fall into the following categories, which represent the different types of activity that can occur within a CAL package.

3.1.1.1. Navigation.

By navigation, I mean the route taken through the program. In the module I constructed, which I designed to have a logical flow to it, the main navigational factor is the linearity or directness of the route. I would expect some people to work through from beginning to end (more or less) and others to take a non-linear path, jumping around out of sequence. Also relevant is the extent to which screens are revisited.

3.1.1.2. Involvement in Screen Activities

Several of the screens in the program are interactive i.e. the user can affect what takes place. I was interested in the extent to which the user chose to carry out the tasks set, and also the extent to which they tried out their own ideas e.g. by altering parameters and watching the results. I was also keen to note any tendencies to repeat tasks.

3.1.1.3. Requirement for Help

The program offers as much help as is required to carry out any screen activity or in deciding which screen to visit next. I was keen to note the frequency of requests for help. Another possibility is to study the pattern of occurrence of such requests i.e. someone could ask for help at the beginning, but come to rely on it progressively less as they work through.

3.1.1.4. Total Time Spent in the Module

I am also interested to observe whether or not there is a range of elapsed times across the group. Some people may rush through, others may take more time.

3.1.2. Is Learning Style Involved ?

To take this a stage further, I wanted to find out if the individual's learning style had any bearing on they way they worked through the program. The first stage in answering this question is determining the individual's learning style. A learning styles questionnaire based on an earlier test formulated for secondary school pupils by Al-Naeme [**19**] was used to measure the student's learning style.

I discussed both motivational and field-dependence factors earlier as ways in which individual students' learning styles differ. However, I decided to focus only on motivational aspects of learning style. This was mostly because it seemed easier to develop a working model for the correlation between motivational type and working style than to do the same for field independence and working style.

3.1.3. Link Between Working Style and Learning Style

The second stage is to look for patterns occurring in the relationship between the working style and the learning style shown up by the software and the questionnaires respectively. So what connection is to be expected, if any? I predicted a reasonably polarised spread of results in which the individual exhibited one of two quite opposite ways of working through the program.

3.1.3.1. The "By the Book" Approach

This first approach can be described as linear or "start-to-finish". Here, the student visits the screens in the order suggested and carries out most activities as instructed. In this mode, there is little spontaneous exploration or activity. It might be expected that help would be requested more frequently, since this student likes the sense of being on the correct track. The student is motivated primarily either to get through the task (the achiever type) or to fulfil a sense of obligation to complete the task (the conscientious type). I would expect most of these students to have a predominantly achiever or conscientious motivational type. It would seem logical to predict that these students would choose to work in "Step-By-Step Guide" Mode (see **Section 3.4.5.1**).

3.1.3.2. The "I Did It My Way" Approach

The second approach can be thought of as non-linear and exploratory. Here the student makes his own way through, paying less attention to the suggested order of visiting screens or carrying out activites. Such individuals would also be expected to spend more time on the kind of activites that presented opportunities to change the working parameters. In general such students would be expected to request help less frequently as they prefer to try things for themselves. I would expect such individuals to have a curious tendency and that they would tend to choose to operate in "Work in My Own Way" mode (see **Section 3.4.5.2**).

3.1.3.3. Other Approaches and Some Difficulties

However, the different learning styles may show up in different ways to those described above. It is possible that a curious student may choose to see the screens in order but spend time exhausting the screen activities. They may also go through from start to finish to get a feel for the size of the module, then having seen it all, go back and jump around in a more exploratory fashion.

It is clear that the social student does not seem to fit neatly into any of the approaches already discussed. Beyond expressing a preference to work with other people rather than working alone, it is difficult to imagine how a social leaning would map onto a specific working style in terms of the different inputs mentioned above e.g. navigation, asking for help etc. if indeed it would have any discernible effect at all. Also, some social students may feel alienated by the student:computer ratio of 1:1 since they prefer group-based activity. Thus, it is possible that they might not actively engage with the program. A parallel hypothesis which is not tested by this research is that the social student is the hardest to cater for using CAL partly because they are the hardest to motivate to learn in a one-to-one CAL environment.

However, we face a problem straight away. There can only be meaningful links if the individual's behaviour in the program has something to do with learning i.e. that they experienced a certain amount of learning motivation as they moved around the program. To increase the chances of eliciting a genuine desire to learn, I decided to choose the test subjects carefully.

3.2. Choice of Test Subjects

To increase the chances of producing learning motivation in the test subjects, I tried to ensure that the subject matter dealt with by the program and the academic subjects being studied by the student recruits were as close as possible. People are motivated by what interests them. Furthermore, the perceived irrelevance of a subject is a well-documented motivation drainer for students. Thus I attempted to reduce the effect of the subject matter variable by matching up in this way.

I wanted volunteers to take part in this experiment since by volunteering, individuals indicate at least a general interest. Volunteers in general are more likely to experience motivation than unwilling conscripts. It could also be said that this self-selection introduces a bias, but if the bias is towards motivation rather than apathy, that is fine. It may mean moving the base line a little when drawing conclusions at a later date.

The experiment was carried out in two stages.

- Pilot Tests
- The Main Experiment

3.2.1. The Pilot Tests

These were carried out for several reasons: most obviously, to allow me to identify blips in the program content e.g. omissions, spelling errors, badly explained concepts, unclear instructions etc. and to eradicate bugs to ensure the software worked properly for the main experiment. I was also able to judge approximately the time required to work through the program. Also, it allowed me to try the program with volunteers drawn from a range of backgrounds just to see what happened.

This group consisted of five people - a statistical computing consultant with much computer experience; an undergraduate politics student with a little computing knowledge; a registered nurse; a postgraduate statistics student with good computing expertise, and a computer scientist with much computer-assisted learning (CAL) experience. All of these individuals took part on their own.

An important point to make here is that the three of the pilot testers had some connection with statistics, computers or both. The remainder of the group became involved through spontaneous interest in the project. It was hoped that although being asked to test the program, that each of the testers would enjoy learning from it also. This is important if their results are to be considered in the final analysis.

3.2.2. The Main Experiment

The main experiment was carried out by a group of twenty students, all of whom were studying at Glasgow University at the time. The group breaks down as follows.

	2nd Year	3rd Year	Postgraduate
Microbiology	0	8	0
Statistics	1	7	4

Table 3.1. Composition of the Test Group

The 3rd year microbiology students had, at the time of taking the test, completed a ten-lecture course in basic statistics, and had covered material similar to that contained in the program. Three lab sessions were run. In the first, thirteen undergraduates took part. In the second, four postgraduates, and in the third, the remaining three undergraduates.

A sample size of twenty-five is not large. However, it should be noted that the pool of volunteers from which the above sample was eventually acquired is limited in size by the need to have students from certain classes (microbiology and statistics) at a stage where they have covered enough material to make sense of the program content. The classes in question have between nineteen and thirty-five students in them. At least sixty students were approached about taking part. Of these, about thirty volunteered, and of this number, twenty turned up to take part in the test.

Also, since this study is very much a "toe in the water" exercise, a large number of subjects is not required. By this I mean that the purpose of the research carried out was partly to indicate the areas of interest which might prove fruitful for further study. Obviously, I was hoping to be able to draw some conclusions about learning styles in the process.

3.3. The Experimental Procedure

The test subjects turned up for a single 60-minute session. This broke down into the following sections.

- Working through the software.
- Two questionnaires - one to establish learning style, and one for their general feedback about working through the software.
- Light refreshments (a small incentive).

Each student worked singly - one student per computer. This is absolutely vital. If there was more than one student per machine, the individual results would simply be some kind of group average, and the student-specific factors which I was hoping to measure would be obscured.

3.4. The Software

When someone knows they are being tested, biases can creep in to the test results. Thus, I decided to conceal the nature of the test behind some independent "front end". It was clear that this front end must be able to stand alone as an activity in its own right. In other words, it would have to be sufficiently engaging to capture the students' attention in itself. Only then would the test be concealed. More importantly, though, if the front end was seen as insubstantial by the user, it would not elicit the desire to learn. As a result, the learning style (which I was looking for) would not be exhibited, and thus the individual's behaviour would not necessarily have anything to do with learning.

3.4.1. The Philosophy of Information Gathering

Again, I felt it was vital that the program didn't feel like a test. This left me with the problem of gathering the information without appearing to ask for it, in other words, "on the fly". The students were made aware that the program monitored their progress in some way, but were not given detailed information. Also, I stated that I would discuss any aspect of the experiment with the students afterwards, including giving a precise definition of what information I had gathered.

The information I wanted from each student could be expressed mostly in the form of questions. It seemed that there were two possible ways of asking each question.

3.4.1.1. Asking Directly

Firstly, a question can be asked directly, demanding an immediate response. This method was used at the beginning of the program regarding their initial choice of working mode (see **Section 3.4.5**). Sometimes it is necessary to collect information in this way if some pending decision depends on it. However, ask too many of the questions in this way and the program may feel like a test to the student. It becomes obvious what information the experimenter wants to know, and the student may spend more time thinking about the test that about learning anything. This is an example of the biases mentioned in the last section.

Direct questioning can produce unnatural responses if it forces someone to ask a question they wouldn't have asked themselves in such a direct way, if at all. In such a case, the result may be anxiety and possibly a misleading or incorrect answer. Questionnaire anxiety is a well-documented syndrome. Misleading answers may also result if people don't know themselves very well. People who are not by nature self-analytical may never have considered the question posed to them on the screen.

3.4.1.2. Asking Indirectly

Secondly, the question can be asked by presenting the student with an opportunity to behave in a number of ways, and noting which option is chosen. This is tantamount to asking the question without asking it. At the end of chapter 2 (see **Section 2.3.4.3**) I discussed the process of weaving direct questions into the fabric of the program. However, it ended up that most of the information I gathered was collected in this more indirect way. In this case, the student does what they want to do, hopefully without thinking "What will it mean if I do this?".

This method was used in several cases e.g. regarding asking for help. There is a button labelled "HELP" on every screen. Its very presence asks the question "Do you want help?". Clicking it regularly or repeatedly probably equates to "Yes" whereas ignoring it may well mean "No". The student is not aware that this choice contributes to the answering of one of the experimental questions.

This second method is free from most of the problems associated with asking directly. It can be though of as a "fly on the wall" approach and is designed to gather the necessary information from the student without influencing their decision-making processes. I believe that on this basis it is more likely to represent the student's true, natural response, though it requires more interpretation afterwards than the more direct method.

3.4.2. Choice of Subject Matter

The choice of which subject to deal with in the program was guided partly by the availability of students in certain subjects at the University where I work. My own degree is in microbiology and I write teaching software for the Statistics Department at Glasgow University, so a program combining microbiology and statistics seemed an ideal choice as it would allow me to draw students from both subjects. The statistical process of random sampling can be easily illustrated using a microbiological sterility test as an example, since the test involves randomly selecting twenty ampoules of vaccine from a large batch to test for microbial contamination.

3.4.3. General Information

The software is mouse-driven and runs under Windows on PC-compatible computers (see **Appendix 2** for more information). Most of the activity on the student's part involves clicking on screen hotspots (or "buttons") with the mouse. The student can navigate between the individual screens using on-screen navigational facilities. There is also a map which gives an overview of the module and indicates which screens have been visited previously. A sample screen shot is shown below. A larger selection of screens is included in **Appendix 2**.

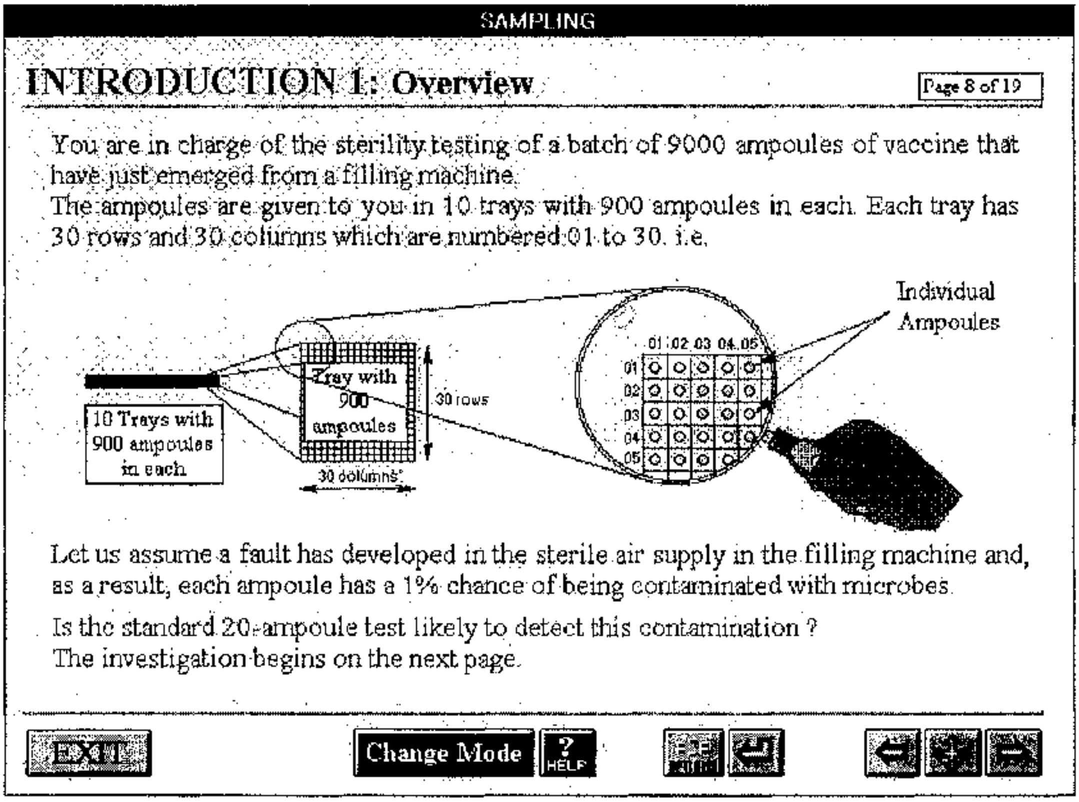


Diagram 3.1. Sample Screen Shot from the Test Program

3.4.4. The Teaching Content

It was essential to get the amount of content right. Too little and there would be insufficient material for the student to get involved in. The program content breaks down into the following sections which can be tackled in any order (after completing the first section listed below).

- Registration and Selection of Initial Working Mode

  The student enters their name and course. They must also choose a working mode at this point. See section **3.4.5** for more details on working mode.

- Background Information

  This section outlines the purpose of the test and its usage in the real world.

- Introduction

  In this section the scene is set, and more detailed information is given about the test and how it will be carried out in the program

- The Test Procedure

  Here, the test procedure is described and demonstrated. The student can carry out several practice runs involving single ampoules to get a grasp of the process of random sampling before carrying out a full test.

- The Experiment

  The students can then carry out as many full 20-ampoule tests as they wish, and are offered the chance to alter certain parameters, namely contamination rate and sampling method and carry out tests with the new values and observe the effects.

- The Big Picture (Statistical Framework)

  In this section, statistical aspects of random sampling are outlined using the sterility test procedure they have explored to illustrate the basic concepts. Firstly, they can investigate the process of deciding how many contaminated ampoules would turn up over a large number of batches given certain contamination rates. Then they can investigate the relationship between contamination rate and the probability of detecting contamination.

- Summary and Test

 The presentation concludes by summing up the main points covered, and offers a short multiple-choice test to finish.

3.4.5. Working Modes

To allow students with different learning styles to get involved in learning from the program, it was clear that flexibility was required. In other words, each student must find that the program allows them to work in their own preferred way. Ideally, the program should not force any unwanted activity upon a user. Neither should it prevent them from doing what they might reasonably expect to be able to do. If the different ways of understanding a given concept are not well known, it makes sense to offer a range of approaches to increase the probability of a student finding one that suits them.

The system used by the program offers different "working modes". These are designed to create a working environment which constrains as little as possible on the one hand (to avoid frustrating the curious students) while offering as much guidance and help as required on the other (to give the conscientious student a greater sense of security).

At the beginning of the program, the student is asked how he would like to work through the program. In response to this question, the student chooses one of the two working modes offered. I will explain the working modes below. It should also be noted that the user can switch modes at any point in the program.

I felt it was necessary that one of the working modes should allow as much freedom of movement as possible as some students may only learn properly when offered it. Within this, students are free to select a more guided environment, and, having selected the more structured mode, can elect to switch to the more open mode.

The two modes are "Step-By-Step Guide" and "Work in My Own Way".

3.4.5.1. Step-By-Step Guide

In this mode the student navigates through the screens in sequence, going backwards or forwards as desired. The screens were ordered to present students with one logical route through the program should they wish to follow it. It is quite possible that there are other routes that make logical sense. In this mode, the student cannot jump to a page out of sequence. However, this mode only restricts the student in terms of navigation. Once on a page, the student is not constrained to carry out the activities there in any given sequence.

This mode was intended to cater for those students (the conscientious and achiever types) who prefer to have their learning controlled by the teacher (or the computer in this case as it is acting in a teaching capacity). It was hoped that the structured navigational style coupled with clear screen instructions would create a secure environment for the conscientious students.

In each of the two working modes, the buttons at the foot of each page reflect the navigational and other options available to the student. The buttons in this mode are

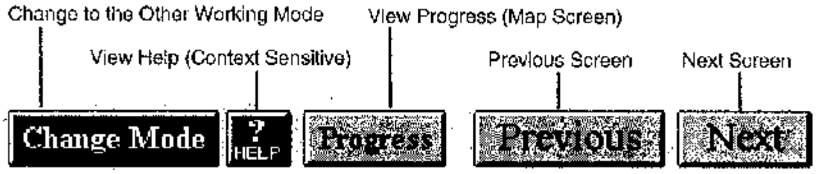


Diagram 3.2. Buttons used in Step-By-Step Guide mode

In addition, the on-line help is more detailed in this mode. Also, the map can only be used to get an idea of where you are - you can only return to the page you came from.

3.4.5.2. Work in My Own Way.

This mode allows the student complete freedom to visit the screens in any order. There is no restriction whatsoever on the student's movements. In this mode, the map can be accessed from all screens and using it, the student can jump to any screen in the module. It was envisaged that the curious students would prefer this mode as they exhibit a clear preference for a more open-ended learning environment.

The buttons in this mode are shown below.

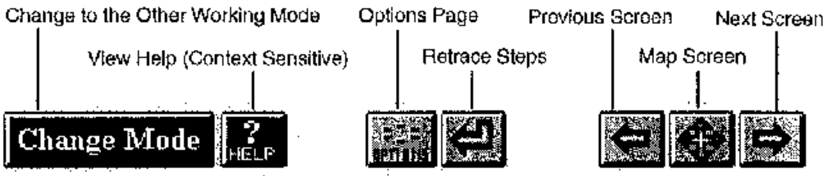


Diagram 3.3. Buttons used in Work in My Own Way mode

In addition, the on-line help is less detailed in this mode.

3.4.6. Tracking Student Activity

3.4.6.1. The PageTrack Mechanism

As already discussed, I needed to devise a means of logging every action the students took in order to have a record of their activity within the program. This log would include navigational information i.e. the exact route taken through the program. I also needed to record what the students did on every page i.e. which of the activities presented were attempted, again noting the frequency and order of occurrence. It was also crucial to record any special activities such as changing working mode, asking for help and so on.

The system developed to do this I called the "Pagetrack" mechanism, and will refer to it as such from now on. Using this system, every action is represented (usually) by a one-character code: pages visited as lower case letters; on-screen activities (such as plotting a graph) as digits, and a range of special codes for other actions such as changing working mode. The system holds a log of all actions taken and is updated simply by adding the code for the latest activity onto the end. Thus the log file represents a chronological list of all actions taken since the program was loaded.

Full details of the system can be found in **Appendix 2**. To give a flavour of the system, consider the following example. Each of the characters in the following example represents a page visited, an action taken, or another action such as asking for help.

```
fgh11?
```

Example: The user went from page 'f' to page 'g' and then to page 'h'. On page 'h' activity '1' was carried out twice. The student then asked for help.

3.4.6.2. The TimeTrack Mechanism

I also decided to log how long (in seconds) the student spent on each screen. By comparing the PageTrack and TimeTrack readings, it can be ascertained how long was spent on every screen. A sample timetrack is show below.

```
48 112 31 15 33 64
```

Example: The student spent 48 seconds on one screen, 112 on the next etc.

This information, in conjunction with other results, can be useful for detecting certain student types e.g. the achiever student who by nature is motivated by the desire to get to the end of the task. Such a student may log a lower than average time per screen. A brief stay on each screen might also suggest that the user was flicking through the screens without paying much attention. In this case, it is unlikely that they would learn much. There are a number of possible explanations for this kind of result which is why it would have to be viewed alongside other data.

3.5. The Questionnaires

3.5.1. The Learning Styles Questionnaire

This is a simple questionnaire in which the student is presented with sixteen items in four categories which relate to different aspects of their university life. Categories are "About class work and lectures", "About lab work", "About exams" and "About socialising". Each category contains one item for each of the four motivational styles - Conscientious, Achiever, Curious and Social. It is not indicated on the test sheet which item belongs to which category. They are asked to select the item from each category that they think best describes themselves. The list of items chosen gives a simple profile for that student. The questionnaire can be seen in **Appendix 1**.

3.5.2. The General Questionnaire

This was designed with three purposes in mind. Firstly, to give me a general impression of how the students had perceived the experiment. Secondly, and more specifically, it yielded an impression of how motivated each student had been, and through this a rough sense of how likely it was that they had been motivated to learn i.e. had their real motivational style influenced their decisions as they moved around the software.

Thirdly, it presented an opportunity for me to get hold of some information that otherwise seemed difficult to acquire. As discussed above, of all the four motivational types, the social student is the hardest to detect by the above experiment.

Thus, I had to think of other ways to detect the socially-motivated students. Among the questions were ones that asked if they would have preferred to work in groups. Also, on the recruitment form, I asked each student if they would mind taking the test on their own at another time in the event that the lab spaces were oversubscribed, or if they would prefer to work in the main group session.

I am fully aware that any response of this type given by a student could have numerous explanations. This is why I treating them in broad terms as 'soft' indicators rather than as hard diagnostic facts.

3.6. Summary

Does learning style affect working style? To answer this I wrote a teaching program that recorded all user activity e.g. route taken, activities carried out etc. I also determined each student's learning style using a simple questionnaire. Other relevant information was gathered in a second questionnaire. I was looking for correlation between certain working styles (which I predicted would be quite polarised) and certain learning styles (motivational patterns exhibited in learning). In the next chapter I will set out the results of this experiment.

CHAPTER 4

Experimental Results

In this chapter I will set out the results of the experiment. To begin with, I will discuss the results I was expecting, then I will go on to set out in detail the data gathered: the results of the learning styles questionnaire, all of the information gathered and derived from the pagetrack data (software output); general facts about each student's involvement from the results of the general questionnaire, and finally some observations made on the days of the experiment and afterwards which shed more light on proceedings.

4.1. Predicted Results

What results should be expected? This has been hinted at in the previous chapter, but I will now examine this question in more detail. The following predictions were made in light of how students with the different learning motivations prefer to work in other learning situations.

4.1.1. Differences in Behaviour Between the Motivational Types

Firstly, let us examine the predicted differences in the style of working adopted by students with the different motivational types. The two main areas of consideration are those of **navigation** i.e. where the student went, and **activity** i.e. what they did when they got there.

4.1.1.1. The Conscientious Student

As previously discussed, the conscientious student is motivated by the desire to discharge a sense of duty to perform the given task adequately.

In terms of navigation, he is likely to prefer following a suggested path rather than go off into free exploration. This trait is manifested by the conscientious student in most learning situations. This might suggest that the screens would be visited in the suggested order i.e. in a linear fashion. In addition, I would not expect a high frequency of out-of-sequence jumps to be made as this would mean departing from the safe pathway. I would expect most screens to be visited few times, perhaps only once, as the student is not asked to revisit any screen and each screen can be completed in a single visit. I would expect a reasonable amount of time to be spent on each screen as this is required to absorb the information and carry out the required activites.

Regarding activity, I would expect that this type of student will perform most of the tasks asked of him to a reasonable standard, but will not, in general, engage in active questioning and exploration of the task. Interactive tasks i.e. those allowing the student to alter the parameters of what happens, would not tend to be repeated a large number of times, as repetition with a wide range of parameters is not a required task at any stage.

In summary, the pattern exhibited by the conscientious student is characterised by a lack of risk-taking and a general compliance with the suggested route through and activity in the program.

4.1.1.2. The Achiever Student

This student, as discussed in chapter 2, bears a strong resemblance to the conscientious student, but differs in several ways. The achiever student is motivated primarily by a desire to achieve; to finish and by a strong liking for competitive learning.

Thus, in an effort to finish quickly, the achiever student might be expected to follow a similar path through the program as that taken by the conscientious student i.e. start to finish without much deviation. However, unlike the conscientious student, the achiever is more motivated by completion than by dutiful execution of the task, so he would probably move along at a greater speed to get to the end. Thus, at a glance the route taken by the achiever would be similar to the one chosen by the conscientious student.

In terms of activity, the achiever is likely to carry out most tasks presented, as they represent small opportunities for achievement. Like the conscientious student, the achiever may not engage in a fuller exploration of the tasks presented, as he may consider it finished after one or two repetitions. Further repetition would not add to the sense of achievement. I would expect the achiever student to take every opportunity offered to assess his progress - the achiever is likely to take the test at the end of the program as it offers just such an opportunity.

4.1.1.3. The Curious Student

How is a curious student likely to behave? Perhaps the most obvious pattern is one which is characterised by a desire to explore, the desire to try out the student's own ideas and to find a path through the new information that satisfies his curiosity about it.

The navigational pattern exhibited by this motivational type is likely to be the most distinct from the others, characterised by a much greater degree of freedom in choosing a path through the program. In other words, I would expect the path to be much less linear overall, perhaps with a greater number of jumps to pages out of sequence. It is also possible that there will be a much greater degree of page revisitation as the student makes sure all of the paths have been fully explored. It is possible that the curious student may choose to go straight through to the end to get a sense of the size of the module, then proceed thereafter in a more exploratory fashion.

Again, in terms of activity, it is likely that the curious student will spend much more time exhausting the activities presented by trying a wide range of parameters, stretching the activities to their limits to see how far they go and so on. It is probable that the exact behavioural pattern exhibited by any given student will be some mixture of the above i.e. for one student, the curiosity is directed more towards the navigational aspects of the program, whereas others may be more motivated by the desire to exhaust the page activities.

4.1.1.4. The Social Student

Of all the four types, I believe the social student is the hardest to detect by this type of experiment. This is simply because the character traits that define the social student are not easily detected by the computer e.g. discussions with other students, greater social awareness etc. What effect do these traits have on the student's navigation and activity in the program? It is difficult to say. The computer cannot know if an answer entered was agreed by a group of students working together or if it was derived by someone working alone. Likewise, the computer cannot tell if a student chose to copy the answer from their neighbour.

4.1.2. What Other Divisions Might be Visible ?

Although the main thrust of the research was to look for links between learning style and working style, it is also possible to see other divisions in the data. In the end, the test group consisted of sixteen undergraduates, four postgraduates and five pilot testers. It is possible that the undergraduates might behave differently from the other two groups. Specifically, we might consider a "subject experience" or "stage" variable which describes how much experience of the subject matter and the teaching medium each test subject has, and also what stage each test subject is at with that subject i.e. are they likely to be examined on material similar to that dealt with by the program? Thus, it is possible that "subject experience" might have an effect on working style.

As always it would make sense to attempt to assess the relative contributions of the learning style variable and the subject experience and other variables in giving rise to the working style of any given student.

4.2. Using All of the Data as a Single Dataset

My original intention was to work only with undergraduate students who were studying either (or both) of the subjects dealt with by the test program. This was explicitly to narrow the range of certain variables e.g. subject experience as already discussed. However, the response level made it necessary to widen out a bit and draw in some others to make up a reasonable number.

The test group I ended up with breaks down into undergraduates, postgraduates and pilot testers. This begs the question - should all of these be grouped together and treated as a single group? I felt that they should - because of the small sample size, I simply can't afford to discard data. However, this approach requires caution since the inclusion of all test participants in one group widens the context. It is important at this point to consider the involvement of the pilot testers. They were given no guidance as to how to work through, only that they were to make notes on any problems encountered. This undoubtedly has some bearing on their activity in the program, and will be taken into consideration when drawing conclusions.

An unexpected feature that came to light in retrospect was that some quite noticeable differences were obvious when comparing the undergraduate results to those of the postgraduates and pilot testers. These will be outlined in this chapter. In this regard, one of the pilot testers did not take the learning styles test, so the total number of data points will be one less when discussing learning styles.

4.3. Information Desired

In broad terms, I am looking for three sets of facts about each student. Firstly, their learning style (or more specifically, motivational style). Secondly, their preferred mode of working in a CAL environment, and thirdly, their individual attitudes to the experiment itself. The learning styles questionnaire will provide an answer to the first question, and the output from the teaching program and the more general questionnaire will help to answer the second. The general questionnaire will also provide some answers to the third question.

The general strategy is to look for any variables which might be useful for describing differences between the different groups, and which variables give a flat response. This information will be used to build up a profile of what kind of working style tends to be chosen by students with different motivational styles. Ultimately, the hope is that this information will be built into teaching software to cater more effectively for individual students.

4.3.1. Why These Variables ?

The big question early on was exactly what information to extract from the raw data. I spent a lot of time thinking about which individual variables could potentially contribute towards the answering of the main questions about learning style and working style and the interaction between them. At one extreme, the raw data is presented as it is, and the reader would be left to try to decipher it by eye. At the other, a very long time is spent squeezing every conceivable variable out of the raw data, producing a list of variables most of which are meaningless.

Using some of the references already cited, I created a master table containing as many criteria as I could find which might be useful in discriminating between the behaviour of those with the different learning styles. I then looked through this list for the criteria which seemed to discriminate the best between some or all of the learning styles, and used these as the basis for deciding which quantities or variables might vary between the learning styles.

So each of the variables generated from the raw data was generated with a specific purpose in mind. Some of them were derived in an attempt to describe and classify the route taken through the program; some to give an idea of how involved the student got with the various screen activites and so on. As each variable comes to be discussed in this chapter, it will be introduced by a statement of why it was calculated i.e. what useful insights it was hoped it might yield, and an explanation of how it was derived from the raw data. A complete list of variables can be found in **Appendix 3**.

4.3.2. How Should Numerical Data Be Represented ?

I am continually aware of the small sample size in this experiment. Thus there arises the issue of how to represent certain measurements, specifically percentages. Some measurements, e.g. most of the variables calculated from *within* each student's data (i.e. output from the software) can safely be represented as percentage values since such variables are derived for each student and their accuracy is therefore independent of sample size. It is the measurements derived from looking at the group as a whole where the care must be taken because of the sample size. Percentage values *per se* give no indication of the amount of data used in their calculation. To use a percentage value may imply that it can be extrapolated to datasets with larger sample sizes. This would be a dangerous error here as the small sample size carries a large margin of error and might well lead to wide-of-the-mark conclusions. For all of these reasons, I have endeavoured to stay within the margins of error when drawing conclusions.

Regarding the presentation of tabular data, I chose to show all data points (in descending numerical order) as well as their average. I believe that this gives a better picture of the data than an average alone would give. This approach is only possible because of the small dataset.

It is tempting to carry out detailed statistical techniques on the data, perhaps with the subconscious desire to lend more certainty to the conclusions. I have purposely avoided this, since the error margins involved would be too large. With more data, I would have used some significance testing (e.g. chi-squared test and contingency tables) to look for significant differences in the data.

4.3.3. Facts About Learning Style

Although I have referred to the student's learning style throughout, it is more specifically the motivational style in a learning context that is measured by this experiment. However, I will continue to refer to this as "learning style".

The learning styles questionnaire (see **Appendix 1**) produces a simple motivational profile of the student. The learning style is expressed as a string of four codes, corresponding to the items selected from each of the four categories in the questionnaire. Each answer can be one of the following.

Code	Learning Style
Con	Conscientious
Ach	Achiever
Cur	Curious
Soc	Social

Table 4.1. Codes representing the four learning styles

Each participant is represented by a code. The codes have three components as follows.

- The first letter represents the **subgroup**

  U = Undergraduate; **P** = Postgraduate and **T** = Pilot Tester.

- The second letter represents the **subject being studied**

  M = Microbiology; **S** = Statistics and **O** = Other

- A number is used to differentiate the individual students within any group.

e.g. **US3** = **U**ndergraduate **S**tatistician no. **3**

These codes are used throughout the remaining chapters to represent the individual students. The table below shows the raw output from the learning styles questionnaire for each student. The different learning styles chosen are highlighted for emphasis.

Code	Learning Style	Code	Learning Style
UM1	Con **Cur** *Soc* *Soc*	PS1	Con Con Con **Cur**
UM2	Con Con **Cur** *Soc*	PS2	Con **Cur** **Cur** *Soc*
UM3	Con Con Con **Cur**	PS3	Con **Cur** **Cur** *Soc*
UM4	Con Con Con **Cur**	PS4	**Cur** **Cur** **Cur** *Soc*
UM5	Con Con **Cur** **Cur**		
UM6	Con Con Con **Cur**		
UM7	Con Con **Cur** **Cur**		
UM8	Con **Cur** *Soc* *Soc*		
US1	Con Con Ach **Cur**	TS1	**Cur** **Cur** *Soc* *Soc*
US2	Con Con **Cur** *Soc*	TS2	**Cur** **Cur** **Cur** **Cur**
US3	Con Ach **Cur** **Cur**	TO1	Con **Cur** **Cur** *Soc*
US4	Con Ach **Cur** *Soc*	TO2	**Cur** **Cur** **Cur** *Soc*
US5	Con Con **Cur** *Soc*		
US6	Con Con *Soc* *Soc*		
US7	Con **Cur** *Soc* *Soc*		
US8	Con Con **Cur** **Cur**		

Table 4.2. Results of Learning Styles Questionnaire for all test participants

4.3.3.1. Assigning a Learning Style to Each Student

We now have to take the raw output from the questionnaire generated by each student and decide which learning style it represents. The output of the learning styles questionnaire is not a single code but a list of four usually mixed codes. Each student's learning style will be referred to as his dominant learning style since the student is likely to select items representing more one learning style from the test, thus indicating learning tendencies in more than one direction.

I decided that any student selecting three or four of one type would be assigned a "strong" designation for that motivational type. Selecting two of one type and one each of two others would result in a "mild" designation. Selecting one of each of the four is designated "no pattern".

It is not immediately obvious what to do where two of one type and two of another are selected. Although like the "no pattern" designation there is no single dominant type, it is clearly not the same as "no pattern" since two and two indicates a leaning in the direction of the two selected styles, whereas "no pattern" indicates no preference at all. I decided that the "two of one and two of another" designation would be considered to be "mild" for both styles. This means using these data items twice. This seems the best solution given the small sample size, as to assign separate categories for each "two and two" combination would spread the data out too much when it came to making comparisons and cross-tabulating with other variables.

The distribution of learning styles in the group is shown below

Learning Style	Frequency	Learning Style	Frequency
Strong Con	4	Mild Con	8
Strong Ach	0	Mild Ach	0
Strong Cur	3	Mild Cur	8
Strong Soc	0	Mild Soc	5
No Pattern	1		

Table 4.3. The occurrence of the different learning styles in the group

Because of the lack of data in certain categories in the above table, from now on I will only use those categories which contain data. These are **Strong Con, Mild Con, Strong Cur, Mild Cur, Mild Soc,** and **No Pattern.**

4.3.4. Working Style and Learning Style

The output from the teaching program is a raw string of coded information which contains information about the route taken through the program and the activites carried out on the different pages.

It was necessary to refine this raw data in order to extract certain basic facts and then proceed to calculate the more advanced parameters that I thought might have some significance. The most obvious refinement was to sift out the navigational information from the raw data to allow me to assess the route taken. I proceeded to calculate several variables based on this information. Secondly, I built on this by adding in the data concerning the activites carried out on each page to give a breakdown of exactly what was done on what page. Before I discuss navigation or activity, I will deal with the variables relating to working mode.

4.3.4.1. Working Mode Variables

The first group of variables relate to the working mode chosen by the student. At the beginning of the program, the students are given the choice of the two working modes detailed in chapter 3. To recap, these are

- Step-By-Step Guide (navigation between pages in sequence).
- Work In My Own Way (no navigational restriction).

These working modes will be referred to in tables etc. as **SBS** and **WIMOW** for conciseness. I was interested in three basic facts about their choice of working mode. These are set out below.

4.3.4.1.1. Initial Working Mode

Initial Working Mode is the mode that was selected when the student left the "SETUP" page (the page on which they were asked to choose a mode to start in - see **Diagram A2.1 - Appendix 1**). Thus it may not necessarily be the first mode selected, as the student could have changed his mind before proceeding to the next page. This initial choice is important because it represents the mode the student felt more comfortable with based on the descriptions of the two modes given on the page and not on their experience of the program which at that point, they hadn't really got into.

	Initial Working Mode	
	SBS	**WIMOW**
Strong Con	4	0
Mild Con	6	2
Strong Cur	0	3
Mild Cur	6	2
Mild Soc	4	1
No Pattern	1	0

Table 4.4. Table of Initial Working Mode against Learning Style

4.3.4.1.2. Main Working Mode

Main Working Mode is the mode the student spent the most time in, not measured by the time in seconds, but by the number of page visits made, since working mode has much effect on navigation between pages but very little on the time spent on each page. So then, Main Working Mode is the mode the student was in for most of the page visits. Since the student could change mode at any time, the assumption could be made that they remain in this mode by choice.

This variable is important because it represents the working mode the student felt comfortable in. It will obviously be the same as the initial mode selected if no mode changes were made. The results for this variable are shown in the next table.

	Main Working Mode	
	SBS	**WIMOW**
Strong Con	4	0
Mild Con	6	2
Strong Cur	0	3
Mild Cur	5	3
Mild Soc	4	1
No Pattern	1	0

Table 4.5. Table of Main Working Mode against Learning Style

4.3.4.1.3. Number of Working Mode Changes

I was also interested to keep track of any instances of the student switching to the other working mode. I suppose it is more important to note whether the student changed at all rather than the number of changes made as after one change, the student will have encountered both working modes and therefore it takes a maximum of two changes for the student to end up in the mode they prefer. This kind of activity I would expect to occur more consistently from curious students. The results for this variable are as shown below.

	Number of Working Mode Changes	**Average**
Strong Con	0 0 0 0	0.0
Mild Con	1 0 0 0 0 0 0 0	0.1
Strong Cur	2 1 0	1.0
Mild Cur	1 1 0 0 0 0 0 0	0.3
Mild Soc	0 0 0 0 0	0.0
No Pattern	0	0.0

Table 4.6. Table of Number Of Working Mode Changes against Learning Style

4.3.4.2. Navigational Variables

The second major group of variables relates to the student's route through the program. These will now be discussed in detail.

4.3.4.2.1. Linearity

The principal navigational variable is **linearity**. This is described by a number of specific variables that indicate in some way how directly the student proceeded through the program.

Linetracks

The **linetrack** is a graphical representation of the route taken through the program. It allows a rapid visual assessment of how linear that route was.

Firstly, the navigational information has to be extracted from the raw data. This gives a list of codes representing the exact route through the program. This variable is plotted on the vertical axis (Progress through the module). Then each page in the module is given a code which represents how far into the module it is situated (opening screen = 'a' or 1, final screen = 'r' or 18). The numerical codes are used to plot the graph. This variable is plotted on the horizontal axis (Page Number).

A typical linetrack is shown below.

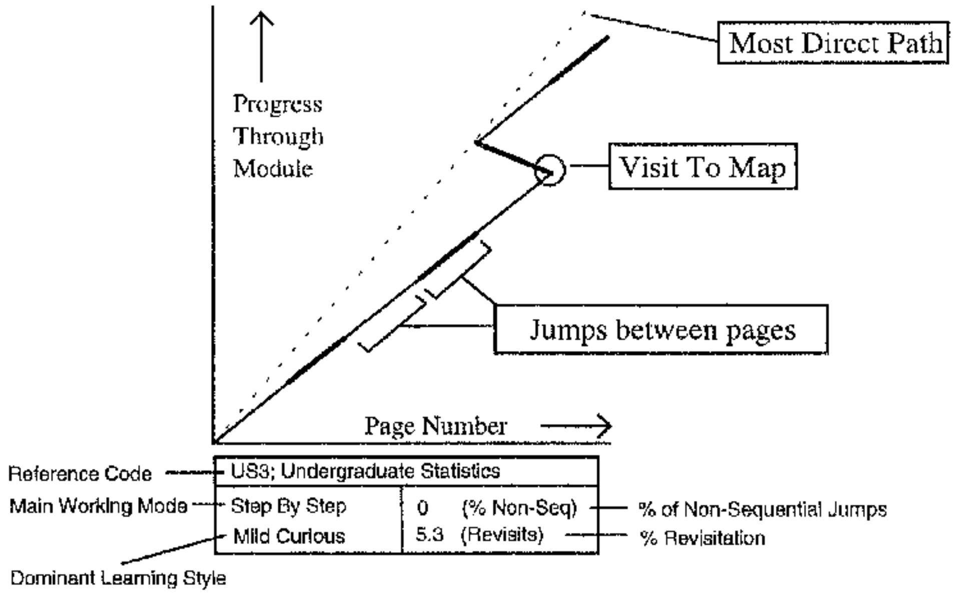


Diagram 4.1. A sample linetrack diagram

Key to Linetrack Diagrams

- The alternating thick and thin line segments represent jumps between pages. The lower end (on the vertical axis) of the line segment is the page the student has just left and the upper end represents the page navigated to. Thus the points of intersection of each pair of adjacent lines represent the pages themselves.

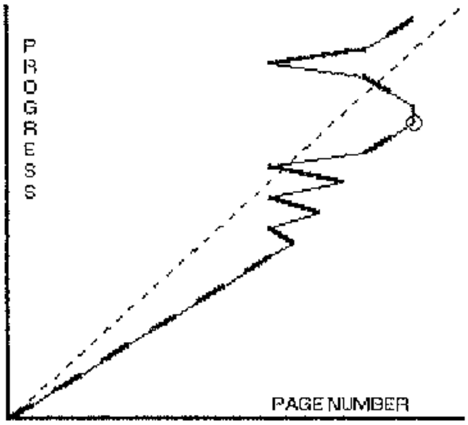
- The line segment beginning at the bottom left corner of the diagram represents the first page jump.

- The dotted line running diagonally across the diagram represents the most direct route through the module from start to finish. The more direct the route, the closer the pattern of line segments will be to the dotted line.

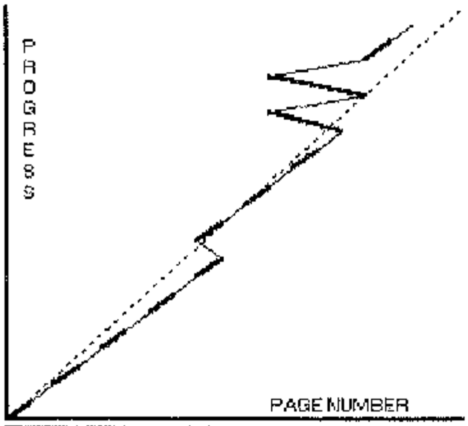
- Visits to the map are not represented as line segments since the map is has no teaching content and is globally accessible, and is therefore logically distinct from the other screens in the module.
  A small circle at the lower end of a line segment represents a visit to the map screen. Look at the upper end of the line segment to see what jump this resulted in. If the line segment is vertical, the student returned to the page they were on prior to visiting the map. Note that only in "Work in My Own Way" mode can the map be used to make jumps to other pages.

The linetrack diagrams for all test participants are shown below. They are arranged into undergraduates, postgraduates and pilot testers.

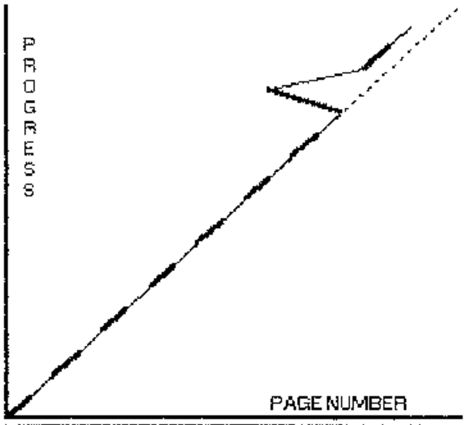
Please turn over.



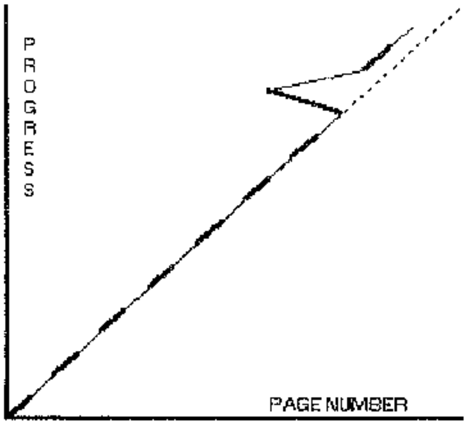
UM1: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Mild Social	35.7	(Revisit)



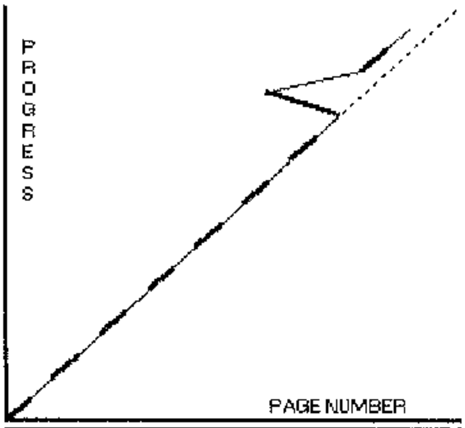
UM2: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Mild Conscientious	21.7	(Revisit)



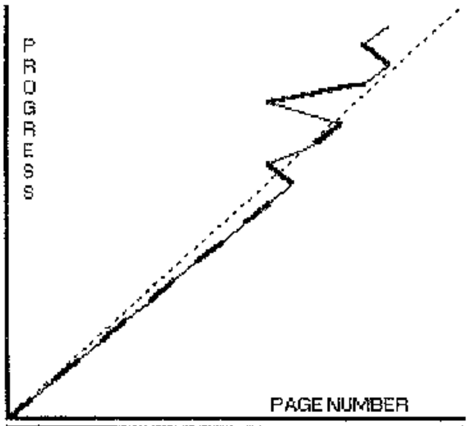
UM3: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Strong Conscientious	5.3	(Revisit)



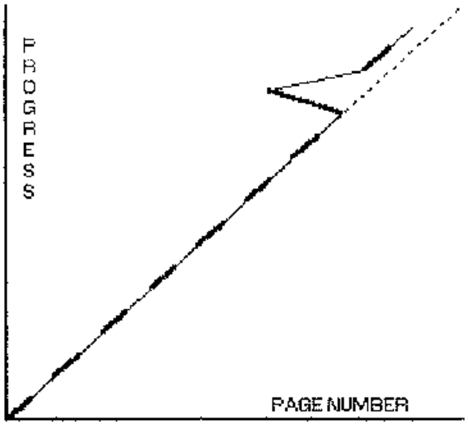
UM4: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Strong Conscientious	5.3	(Revisit)



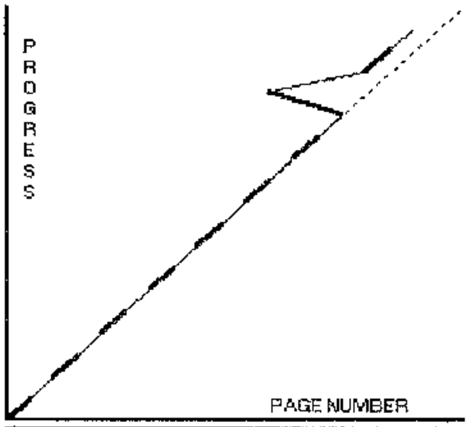
UM5: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Conscientious\Curious	5.3	(Revisit)



UM6: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Strong Conscientious	19.0	(Revisit)

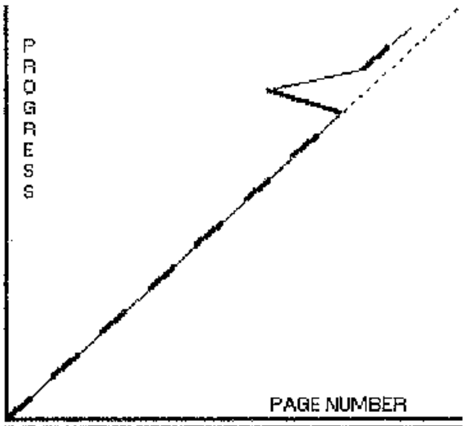


UM7: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Conscientious\Curious	5.3	(Revisit)

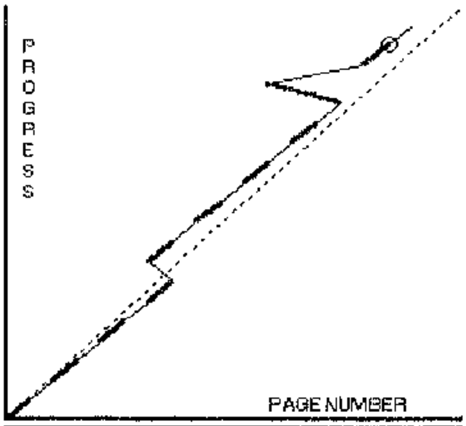


UM8: Undergraduate ; Microbiology		
Step by Step Guide	0	(% NonSeq)
Mild Social	5.3	(Revisit)

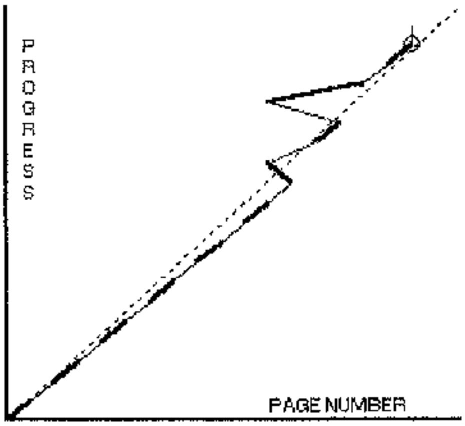
Undergraduate Statistics Linetracks



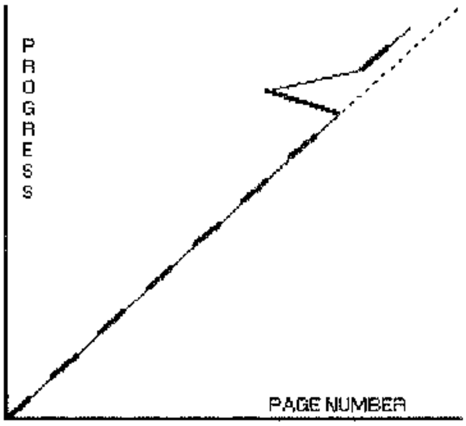
US1: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Conscientious	5.3	(Revisit)



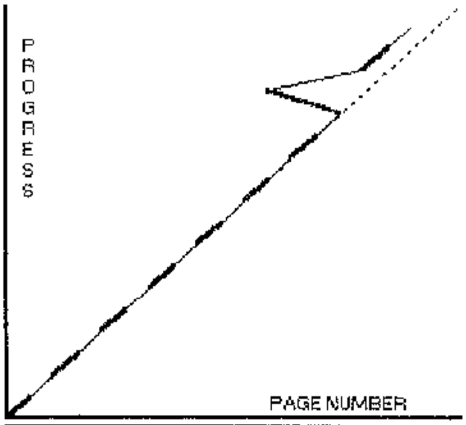
US2: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Conscientious	14.3	(Revisit)



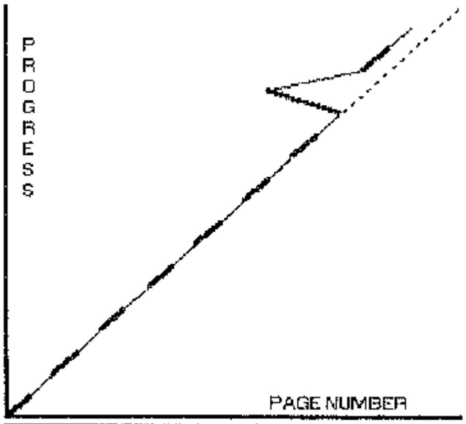
US3: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Curious	14.3	(Revisit)



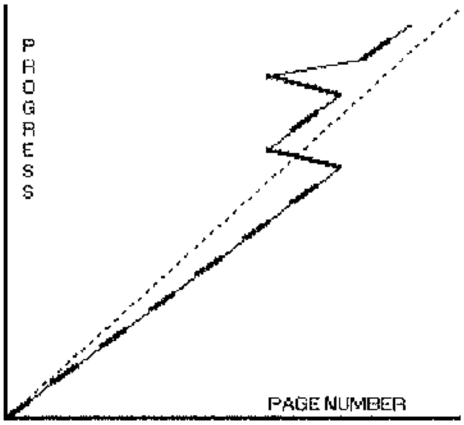
US4: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
No Pattern	5.3	(Revisit)



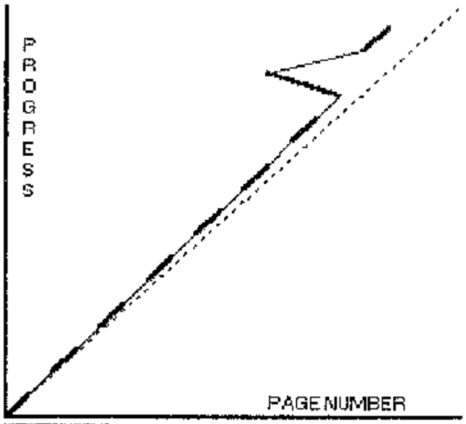
US5: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Conscientious	5.3	(Revisit)



US6: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Conscientious\Social	5.3	(Revisit)

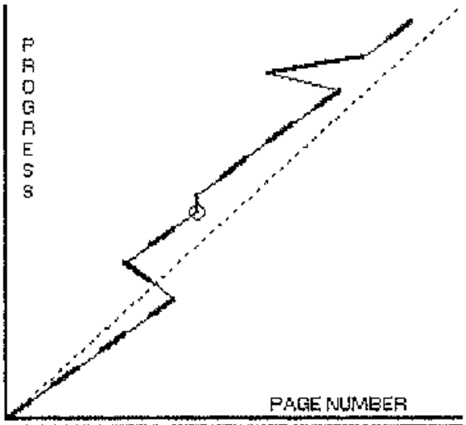


US7: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Social	21.7	(Revisit)

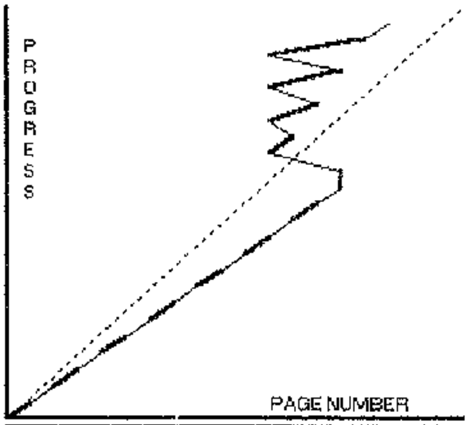


US8: Undergraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Conscientious\Curious	5.6	(Revisit)

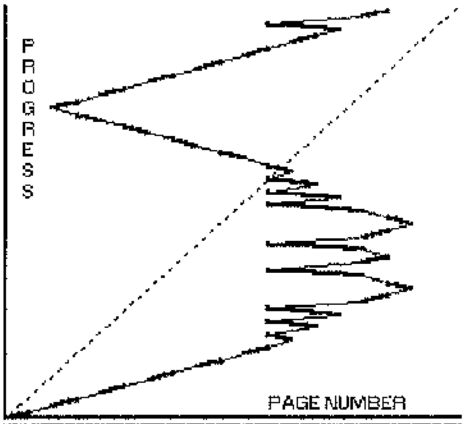
Continued overleaf



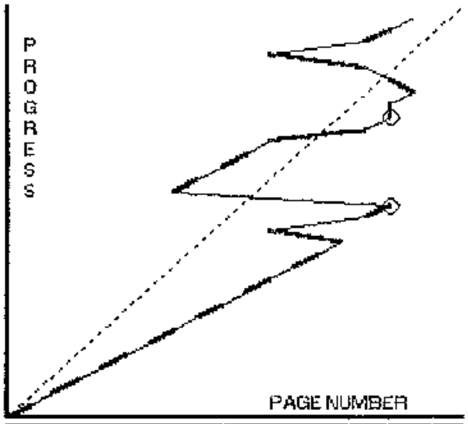
PS1: Postgraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Strong Conscientious	25.0	(Revisit)



PS2: Postgraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Curious	32.0	(Revisit)



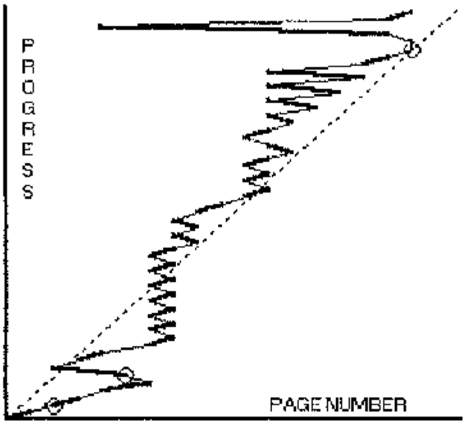
PS3: Postgraduate ; Statistics		
Step by Step Guide	0	(% NonSeq)
Mild Curious	71.9	(Revisit)



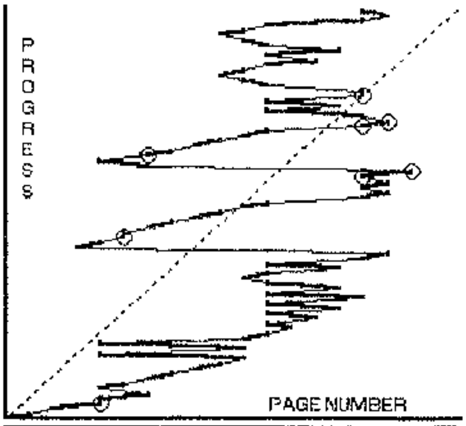
PS4: Postgraduate ; Statistics		
Step by Step Guide	3.1	(% NonSeq)
Strong Curious	45.5	(Revisit)

Continued Overleaf

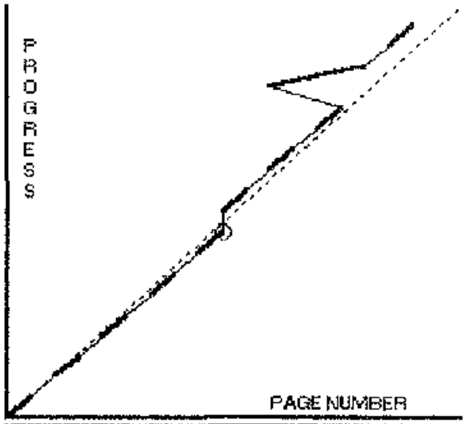
Pilot Tester Linetracks



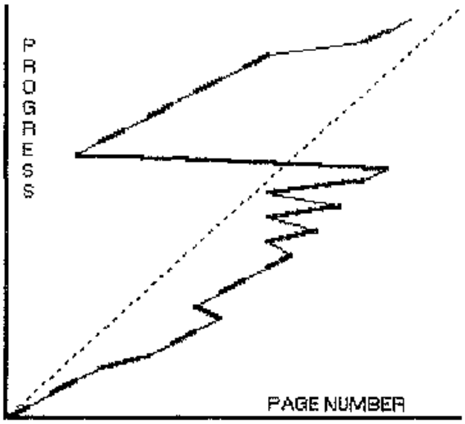
TS1: Pilot Tester ; Statistics	
Step by Step Guide	9.1 (% NonSeq)
Curious\Social	67.9 (Revisit)



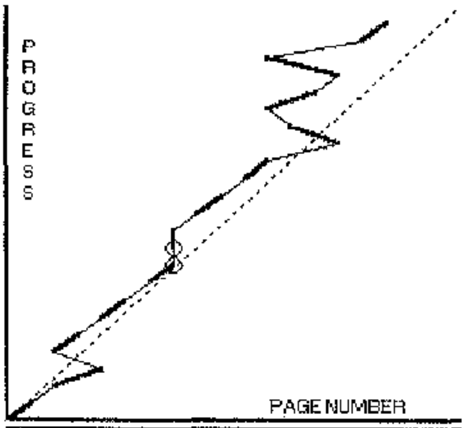
TS2: Pilot Tester ; Statistics	
Step by Step Guide	13.6 (% NonSeq)
Strong Curious	78.0 (Revisit)



TO1: Pilot Tester ; Other	
Step by Step Guide	0 (% NonSeq)
Mild Curious	10.0 (Revisit)



TO2: Pilot Tester ; Other	
Step by Step Guide	3.1 (% NonSeq)
Strong Curious	45.5 (Revisit)



TO3: Pilot Tester ; Other	
Step by Step Guide	17.4 (% NonSeq)
Test not taken	29.2 (Revisit)

Percentage of Non-Sequential Jumps

I was also interested in how many out-of sequence page jumps were made, as a measure of linearity. A linear path is one in which a very low proportion of the jumps are non-sequential.

Firstly, I drew up a list for each page that stated which other pages it was logical to jump to directly without breaking the logical flow. The obvious choices are the next page and the previous page, but in some cases a page leads logically to several others. All logical jumps of this kind are referred to here as sequential jumps. Likewise, a non-sequential jump is one where the logical flow is broken by jumping to a page out of sequence. This could occur via the map, options button, back (retrace steps) button, or the review button. All possible jumps are either sequential or non-sequential.

For each student, I examined all of the page-to-page jumps made and counted those that were non-sequential. I then calculated **Percentage of Non-Sequential Jumps** as the number of non-sequential jumps over the total number of jumps (sequential + non-sequential) and expressed the result as a percentage. The results are as follows.

	Percentage of Non-Sequential Jumps	Average
Strong Con	0 0 0 0	0.0
Mild Con	0 0 0 0 0 0 0 0	0.0
Strong Cur	13.6 3.1 3.1	6.6
Mild Cur	9.1 0 0 0 0 0 0 0	1.1
Mild Soc	9.1 0 0 0 0	1.8
No Pattern	0	0.0

Table 4.7. Table of Percentage Of Non-Sequential Jumps against Learning Style

Percentage Revisitation

As another possible measure of linearity, I was interested to measure the extent to which students revisited screens they had already been to. There are of course many possible reasons for revisiting a page, but I was hoping that a consistent difference might appear between the curious and the conscientious/achiever students. I would expect a greater degree of revisitation from the curious students as a manifestation of their more exploratory mindset, perhaps because they want to make sure all the avenues have been explored on the page, or perhaps as they visit the page en route to somewhere else.

I calculated a measurement called **Percentage Revisitation** which represents the percentage of page visits that were to pages that had been already visited. To calculate this I counted the number of visits to pages that had already been visited, and expressed it as a percentage of the total number of page visits made. Someone working through the module visiting screens only once would generate a value of 0%.

The table below shows the results for this variable. In addition to the average revisitation for each learning style, I have also shown the individual revisitation percentages for each student for completeness.

	Percentage Revisitation	Average
Strong Con	25.0 19.0 5.3 5.3	13.7
Mild Con	21.7 14.3 5.6 5.3 5.3 5.3 5.3 5.3	8.5
Strong Cur	78.0 45.5 45.5	56.3
Mild Cur	71.9 67.9 32.0 14.3 10.0 5.6 5.3 5.3	26.5
Mild Soc	67.9 35.7 21.7 5.3 5.3	27.2
No Pattern	5.3	5.3

Table 4.8. Table of Revisitation against Learning Style

I should point out that there is a "compulsory" revisitation due to the design of the program. There is a little suite of three screens which are all accessed from one central screen. In order to proceed, it is necessary to return at least once to the central screen when working in "Step-By-Step Guide" mode. As will be discussed in the next chapter, I have not compensated for this.

4.3.4.2.2. Percentage of Screens Visited

This is a very simple measurement, and simply represents the percentage of the eighteen pages in the module that were visited (regardless of how often).

	Percentage of Screens Visited	Average
Strong Con	100.0 100.0 100.0 94.4	98.6
Mild Con	100.0 100.0 100.0 100.0 100.0 100.0 100.0 94.4	99.3
Strong Cur	100.0 100.0 100.0	100.0
Mild Cur	100.0 100.0 100.0 100.0 100.0 100.0 94.4 94.4	98.6
Mild Soc	100.0 100.0 100.0 100.0 100.0	100.0
No Pattern	100.0	100.0

Table 4.9. Table of Percentage of Screens Visited against Learning Style

4.3.4.2.3. Number of Map Accesses

The map screen is available from every screen in the module, and it gives the student a diagrammatic representation of where they are in the module and how much has been covered. In "Step-by-Step Guide" mode, the map is accessed via a button labelled "Progress" and in "Work in My Own Way" mode, via a button situated between the next and previous page buttons. See Section **3.4.5** for a reminder of this. The number of times the map was accessed is as follows.

	Number of Map Accesses	Average
Strong Con	1 0 0 0	0.3
Mild Con	1 0 0 0 0 0 0 0	0.1
Strong Cur	8 2 0	3.3
Mild Cur	3 1 1 0 0 0 0 0	0.6
Mild Soc	3 1 0 0 0	0.8
No Pattern	0	0.0

Table 4.10. Table of Number Of Map Accesses against Learning Style

4.3.4.3. Activity Variables

The third major set of measurements are to do with the extent of the students' involvement in the activites presented to them on the various screens. The main reason for keeping track of various aspects of page activities was to gain some idea of how involved the student got in the teaching matter presented by the program.

Before continuing, I must define what I mean by an **activity**. An activity is a clearly-defined task such as carrying out a 20-ampoule test, or taking a short test. Activities usually consist of more than a single mouseclick (or **action**) and are usually associated with a single screen. Thus any navigation, request for help and other such activities are excluded from this definition because they are globally available and are not required for the completion of a screen.

4.3.4.3.1. Percentage of Activities Completed

This is perhaps one of the more obvious ways to test how much the student did. This variable only takes account of the activities carried out on the pages visited. It is calculated by counting the number of activities completed for each of the pages visited ("actual"), then totalling the number of activities available on these pages ("possible") - **Percentage of Actions Completed** is the ratio of actual to possible expressed as a percentage. Where an activity consists of more than one action, it is necessary to define for each activity the point at which it is said to be completed. For example, the student might be said to have completed an activity consisting of a multiple-choice question when the correct answer has been found and not when they have clicked all of the answers. The results for this variable are shown in the table below.

	Percentage of Activities Completed	Average
Strong Con	90.0 80.0 75.0 56.3	75.3
Mild Con	95.0 87.5 85.0 75.0 75.0 75.0 65.0 60.0	77.2
Strong Cur	90.0 85.0 80.0	85.0
Mild Cur	95.0 90.0 87.5 80.0 70.0 68.8 65.0 60.0	77.0
Mild Soc	90.0 80.0 75.0 75.0 70.0	78.0
No Pattern	90.0	90.0

Table 4.11. Table of Percentage Of Activites Completed against Learning Style

4.3.4.3.2. Percentage of Total Buttons Clicked

A similar measurement to the one above deals with the percentage of all the available buttons in the module that were clicked. This measurement does not take into account the navigational and other buttons at the foot of the screen. This time I am counting individual actions and not activities. I took this measurement to try to record the activity of the kind of user who likes to click everything in sight. The results for this variable are as follows.

	Percentage of Total Buttons Clicked	Average
Strong Con	60.0 53.3 50.0 30.0	48.3
Mild Con	63.3 56.7 50.0 50.0 50.0 46.7 43.3 40.0	50.0
Strong Cur	60.0 56.7 53.3	56.7
Mild Cur	63.3 60.0 53.3 46.7 46.7 43.3 40.0 36.7	48.8
Mild Soc	60.0 53.3 50.0 50.0 46.7	52.0
No Pattern	60.0	60.0

Table 4.12. Table of Percentage Of Total Buttons Clicked against Learning Style

4.3.4.3.3. Percentage of Actions Repeated

To take this further, I wanted to know not only the extent to which the student had completed the activities offered, but the extent to which the individual actions making up these activites were repeated. I decided to do this by calculating the repetition of the individual actions as this offers more resolution than measuring the repetition of activities (which usually consist of more than one action). I anticipated that certain students, namely the curious ones, would be more likely to repeat actions consistently, especially those to do with user-variable parameters.

Firstly I calculated the percentage of actions that were carried out more than once, not taking into account the extent of repetition. An example calculation is shown below.

e.g. 11

% Actions Repeated = 100%
(1 repeated action, 1 total)
In this example, all of the actions carried out were carried out more than once, hence the value of 100%.

e.g. 1111234

% Actions Repeated = 25%
(1 repeated action, 4 total)

The results for this variable are as follows.

	Percentage of Actions Repeated	Average
Strong Con	35.0 35.0 23.5 18.2	27.9
Mild Con	61.5 52.9 47.8 45.5 38.9 38.1 23.5 20.0	41.0
Strong Cur	65.2 62.5 39.1	55.6
Mild Cur	84.2 61.5 55.6 52.9 50.0 28.6 23.8 20.0	47.1
Mild Soc	84.2 43.5 38.9 22.7 22.2	42.3
No Pattern	43.5	43.5

Table 4.13. Table of Percentage of Actions Repeated against Learning Style

4.3.4.3.4. Percentage Repetition

The above measurement, however, does not indicate the extent of repetition of page activites, so we need a second variable called **Percentage Repetition**. To calculate this, I counted from the pagetrack data the number of instances where an action was repeated that had already been carried out, regardless of whether they were carried out during the same visit to the page or on separate visits (as before, an action here is a single mouseclick as distinct from an activity which may consist of several actions). This is expressed this as a percentage of the total number of actions carried out. For example ...

e.g. **11112234** (repetitions shown in bold)
Repetition = 50% (4 repeated actions, 8 actions total)

The results for this variable are as follows.

	Percentage Repetition	Average
Strong Con	77.5 74.2 64.5 61.5	69.4
Mild Con	90.4 85.6 79.3 68.9 62.7 54.1 40.0 38.2	64.9
Strong Cur	86.2 72.0 54.0	70.7
Mild Cur	92.9 90.4 89.1 85.6 67.5 66.1 65.9 40.0	74.7
Mild Soc	92.9 79.3 68.5 66.7 63.3	74.1
No Pattern	61.0	61.0

Table 4.14. Table of Percentage Repetition against Learning Style

4.3.4.3.5. Number of Repeated Actions

I feel in this case that the percentage values are masking the underlying trend. So, I decided to tabulate the actual number of repeated actions without reference to the total number as this may give a truer picture of how much repetition occurred. Obviously a value of 50% repetition does not indicate how many repeated actions there were. The results for **Number of Repeated Actions** are as follows.

	Number of Repeated Actions	Average
Strong Con	69 49 32 20	42.5
Mild Con	161 77 69 51 37 20 13 10	54.8
Strong Cur	150 59 27	78.7
Mild Cur	248 213 161 77 56 41 27 10	104.1
Mild Soc	248 69 50 44 31	88.4
No Pattern	36	36.0

Table 4.15. Table of Number of Repeated Actions against Learning Style

4.3.4.3.6. Completion of Interactive Areas

On a slightly different tack, I decided to calculate whether the student had engaged in the most interactive parts of the program. I will deal with each of these now.

Changed Experiment Parameters?

Possibly the screen that allows the most real interaction between student and computer is the screen where the 20-ampoule test is carried out. The student can alter the contamination rate between 0.01% and 99% and test a batch with that contamination rate. The sampling method can also be altered. There is no limit to the number of batches the student can generate. I would expect the curious students to explore a much wider range of contamination rates than e.g. the conscientious students who will probably not experiment extensively with this parameter. The results for this variable are as follows.

	Changed Experiment Parameters?	
	YES	NO
Strong Con	1	3
Mild Con	3	5
Strong Cur	2	1
Mild Cur	4	4
Mild Soc	2	3
No Pattern	1	0

Table 4.16. Table of Changed Experiment Parameters against Learning Style

Graph Interpolation

Later in the program, the student investigates the relationship between contamination rate and the probability of detecting contamination. A graph is plotted of probability against contamination rate, and the student can interpolate along the graph, reading off the probability of detecting contamination for different contamination rates. From each student's pagetrack data, I counted the number of students who did interpolate along the curve and the number who didn't. The result is as follows.

	Interpolated Along Graph ?	
	YES	NO
Strong Con	3	1
Mild Con	7	1
Strong Cur	3	0
Mild Cur	7	1
Mild Soc	5	0
No Pattern	1	0

Table 4.17. Table of Interpolation Along Graph against Learning Style

Test Questions Answered

The final screen in the module is a short test consisting of four multiple-choice questions. The questions are based on the material covered in the module. I wanted to find out how many questions each student had answered, and in doing so, to find out if they had attempted the test at all. The results are as follows.

	Number of Test Questions Answered	Average
Strong Con	4 4 4 0	3.0
Mild Con	4 4 4 4 4 4 0 0	3.0
Strong Cur	4 4 4	4.0
Mild Cur	4 4 4 4 0 0 0 0	2.0
Mild Soc	4 4 4 4 0	3.2
No Pattern	4	4.0

Table 4.18. Table of Number Of Test Questions Answered against Learning Style

I also recorded the percentage of correct answers selected as a percentage of the total number of answers selected. I decided in the end that there were too many reasons for a student generating the result they did to make it a meaningful measurement. However, the table of results for this variable can be found in **Appendix 3**.

4.3.4.4. Other Variables

4.3.4.4.1. Total Time Spent in Module

I was interested to find out how long the student spent in the module. Initially I had thought of making something of how long was spent on each screen. The problem here is that there is such a multiplicity of reasons why someone should spend the time they did on any given visit to any screen that I decided not to take this branch further. However, I felt it would be useful to find out how long the student took to go through the whole module.

The first reading in the timetrack log is always quite high - this is due to the fact that the software was running on each machine before the students came, so that by the time they began working through the software, the timer had already been running for a few minutes. To compensate for this, I replaced the first reading in each student's timetrack log with a reading of 30 seconds, as this seemed to be the time the students were spending on the front screen before moving on.

This measurement is potentially useful (along with other data of course) for detecting achiever students whom I would expect to work at a greater pace on average than the others, and also perhaps in detecting those students who worked at great speed because of lack of interest or motivation. The total times for the group are as follows.

	Total Time Spent in Module	Average
Strong Con	21' 29" 18' 23" 17' 37" 17' 26"	18' 44"
Mild Con	21' 47" 21' 18" 21' 07" 19' 28" 19' 26" 19' 01" 18' 25" 12' 28"	19' 08"
Strong Cur	38' 33" 25' 24" 14' 15"	26' 04"
Mild Cur	35' 29" 26' 12" 21' 07" 20' 52" 19' 01" 16' 41" 13' 03" 12' 28"	20' 37"
Mild Soc	35' 29" 19' 35" 19' 28" 15' 55" 15' 28"	21' 11"
No Pattern	15' 59"	15' 59"

Table 4.19. Table of Total Time Spent in Module against Learning Style

4.3.4.4.2. Number of Requests For Help

On-line help was available for every stage of every page of the module i.e. the help information was specific to the exact stage they had reached in the module. I was interested to find out how often the students requested help. The results came out as follows.

	Requests for Help	Average
Strong Con	1 0 0 0	0.3
Mild Con	3 1 0 0 0 0 0 0	0.5
Strong Cur	3 2 0	1.7
Mild Cur	3 2 1 0 0 0 0 0	0.8
Mild Soc	0 0 0 0 0	0.0
No Pattern	0	0.0

Table 4.20. Table of Number Of Requests For Help against Learning Style

4.3.5. Working Style and the Test Subgroups

As I began to examine the data, it became clear that there were differences between the different subgroups within the test group i.e. the undergraduates, postgraduates and pilot testers as well as any differences due to learning style.

The variables for which there seemed to be the greatest differences are discussed below. Note that all the variables in this section have already been discussed in relation to learning style. Those variables which gave a flat response across the different subgroups may be mentioned in passing here, but the tables representing these variables can be found in **Appendix 3**. The variables discussed in the following section have all been described above, so the results will be shown with little explanation.

Where appropriate, the following abbreviated code is used to for the different subgroups.

Code	Full Designation
U	Undergraduate Student
P	Postgraduate Student
T	Pilot Tester

Table 4.21. Table of codes used to represent the different subgroups in the test group

4.3.5.1. Learning Style

The distribution of learning styles amongst undergraduates, postgraduates and pilot testers is as follows.

	Strong Con	Mild Con	Strong Cur	Mild Cur	Mild Soc	No Pattern
Undergraduates	3	8	0	4	4	1
Postgraduates	1	0	1	2	0	0
Pilot Testers	0	0	2	2	1	0

Table 4.22. The occurrence of the different learning styles for the different subgroups

I decided to count the number of conscientious and curious items selected from the learning styles questionnaire by those in the different subgroups. The table below shows the average number of conscientious and curious items selected.

	Average Con Selected	Average Cur Selected
Undergraduates	1.88	1.19
Postgraduates	1.25	2.00
Pilot Testers	0.25	2.75

Table 4.23. Table of The Average Number of Conscientious and Curious items chosen from the learning styles questionnaire by those in the different subgroups

4.3.5.2. Working Mode

4.3.5.2.1. Main Working Mode

The distribution of the different learning styles amongst undergraduates, postgraduates and pilot testers is as follows. To recap, SBS = "Step-By-Step Guide" mode and WIMOW = "Work in My Own Way" mode.

	Main Working Mode	
	SBS	WIMOW
Undergraduates	14	2
Postgraduates	2	2
Pilot Testers	1	4

Table 4.24. Table of Main Working Mode for the different subgroups

As when plotted against learning style, there are very few students who chose a different main mode and the initial mode, so there is no need to discuss initial mode again.

4.3.5.2.2. Number of Working Mode Changes

There seemed to be some difference between the subgroups with regard to the number of times they changed working mode.

	Number of Working Mode Changes	Average
Undergraduates	1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.1
Postgraduates	1 0 0 0	0.3
Pilot Testers	6 2 1 0 0	1.8

Table 4.25. Table of Number of Working Mode Changes for the different subgroups

4.3.5.3. Navigation

4.3.5.3.1. Linetracks

The linetrack diagrams are shown in a previous section sorted into the different subgroups which is pretty much the way they were gathered. See **Section 4.3.4.2.1**.

4.3.5.3.2. Percentage of Non-Sequential Jumps

There turned out to be quite a clear difference in the percentage of non-sequential jumps made by those in the different subgroups. The most remarkable feature is that not a single non-sequential jump was made by an undergraduate student.

	Percentage of Non-Sequential Jumps	Average
Undergraduates	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.0
Postgraduates	3.1 0 0 0	0.8
Pilot Testers	17.4 13.6 9.1 3.1 0	8.6

Table 4.26. Table of Percentage of Non-Sequential Jumps for the different subgroups

4.3.5.3.3. Percentage Revisitation

Another clear division is visible when considering the amount of revisitation. Again, the undergraduates are engaging in this behaviour much less than students in the other two subgroups.

	Percentage Revisitation	Average
Undergraduates	35.7 21.7 21.7 19.0 14.3 14.3 5.6 5.3 5.3 5.3 5.3 5.3 5.3 5.3 5.3 5.3	11.3
Postgraduates	71.9 45.5 32.0 25.0	43.6
Pilot Testers	78.0 67.9 45.5 29.2 10.0	46.1

Table 4.27. Table of Percentage Revisitation for the different subgroups

4.3.5.3.4. Number of Map Accesses

Almost all of the map visits turn out to have been made by non-undergraduates. The table for this result is shown below.

	Number of Map Accesses	Average
Undergraduates	1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0	0.2
Postgraduates	2 1 0 0	0.8
Pilot Testers	8 3 2 1 0	2.8

Table 4.28. Table of Number Of Map Accesses for the different subgroups

4.3.5.4. Activities

4.3.5.4.1. Percentage of Actions Repeated

Not such a clear division visible for this variable, but again, the undergraduates seem to be repeating the page activities less.

	Percentage of Actions Repeated	Average
Undergraduates	61.5 52.9 47.8 45.5 43.5 43.5 38.9 38.1 35.0 23.8 23.5 23.5 22.7 22.2 20.0 18.2	35.0
Postgraduates	65.2 55.6 35.0 28.6	46.1
Pilot Testers	84.2 62.5 50.0 39.1 35.0	54.2

Table 4.29. Table of Percentage of Actions Repeated for the different subgroups

4.3.5.4.2. Number of Repeated Actions

There is a marked difference in the number of repeated actions when comparing the pilot testers with both the undergraduates and postgraduates. The result of "161" was generated by the student who got stuck on the "EXPERIMENT" page. See **Section 4.4.1** for more details.

	Number of Repeated Actions	Average
Undergraduates	161 77 69 69 51 50 49 44 41 37 36 31 20 20 13 10	48.6
Postgraduates	59 56 32 27	43.5
Pilot Testers	248 213 150 27 23	132.2

Table 4.30. Table of Number Of Repeated Actions for the different subgroups

4.3.5.4.3. Changed Experiment Parameters

There seems to be some difference in the proportion of students in the different subgroups who explore the 20-ampoule test fully by altering experimental parameters.

	Changed Experiment Parameters ?	
	YES	NO
Undergraduates	6	10
Postgraduates	2	2
Pilot Testers	4	1

Table 4.31. Table of Changed Experiment Parameters for the different subgroups

4.3.5.5. Other Variables

4.3.5.5.1. Total Time Spent in Module

On average, the pilot testers spend around ten minutes longer working through the module than the others.

	Total Time Spent in Module	Average
Undergraduates	21' 47" 21' 18" 21' 07" 19' 35" 19' 28" 19' 26" 19' 01" 18' 25" 18' 23" 17' 37" 17' 26" 15' 59" 15' 55" 15' 28" 13' 03" 12' 28"	17' 54"
Postgraduates	21' 29" 20' 52" 16' 41" 14' 15"	18' 19"
Pilot Testers	38' 33" 35' 29" 26' 12" 25' 24" 20' 36"	29' 15"

Table 4.32. Table of Total Time Spent in Module for the different subgroups

4.3.5.5.2. Number of Requests for Help

The average pilot tester used the help facility more than the others.

	Number of Requests for Help	Average
Undergraduates	3 2 1 1 0 0 0 0 0 0 0 0 0 0 0 0	0.4
PostGraduates	0 0 0 0	0.0
Pilot Testers	8 3 2 1 0	2.8

Table 4.33. Table of Number Of Requests For Help for the different subgroups

4.3.6. General Facts

Aside from the specific data gathered from each student regarding learning style and working style, I also realised that it would be a good idea to gauge each student's general attitude to the experiment - their general level of motivation, their interest in what they had done and so on. I also tried to measure, albeit in a very rough way, how motivated each student had been to learn. I should point out that only the undergraduates and postgraduates completed this questionnaire (20 students in total).

Most of the information about each student is learned from the results of their general questionnaire (See **Appendix 1** for the General Questionnaire). This consists of a series of 6 statements to which the student can respond to on a scale of 1 to 5 as follows.

1 = Strongly Agree > **3** = Neutral > **5** = Strongly Disagree.

In general, where there was more than one question addressing the same area, the questions would not be placed together in the questionnaire. In presenting these results, I don't feel it is important to split them up according to learning style or into the different subgroups as I want to examine the general picture at least for the moment. However, any individual results of interest may be highlighted here but will be discussed fully in the next chapter. I will now outline the different measurements made using the results of the general questionnaire.

4.3.6.1. Level of Learning Motivation

Perhaps the most crucial measurement made is the level of learning motivation experienced by each student with regard to the software. By choosing to come, each student indicated at least a certain base level of learning motivation. However, I felt it was important to get some idea of each student's level of learning motivation. The following questionnaire statements were designed to gather information about this.

4.3.6.1.1. Overall Reaction to the Software

- *I enjoyed working through the module* (Questionnaire Statement 1)

	Response	Frequency
1	(Strongly Agree)	6
2	(Agree)	14
3	(Neutral)	0
4	(Disagree)	0
5	(Strongly Disagree)	0

Table 4.34. Response to Questionnaire Statement 1

- *I would welcome computer-based material of this type as part of my course* (Questionnaire Statement 6)

	Response	Frequency
1	(Strongly Agree)	9
2	(Agree)	11
3	(Neutral)	0
4	(Disagree)	0
5	(Strongly Disagree)	0

Table 4.35. Response to Questionnaire Statement 6

4.3.6.1.2. Specific Reactions to the Software

I was anxious also to determine how easy each student found the software to use and the extent to which it allowed them freedom to do what they wanted. I felt this was crucial also as if I got this wrong in the program design, then learning could be adversely affected. The questionnaire items covering this aspect are dealt with next.

- *I found the software easy to use* (Questionnaire Statement 2)

	Response	Frequency
1	(Strongly Agree)	13
2	(Agree)	7
3	(Neutral)	0
4	(Disagree)	0
5	(Strongly Disagree)	0

Table 4.36. Response to Questionnaire Statement 2

- *The instructions given on each page were clear - I always knew what to do next.* (Questionnaire Statement 3)

	Response	Frequency
1	(Strongly Agree)	12
2	(Agree)	7
3	(Neutral)	1
4	(Disagree)	0
5	(Strongly Disagree)	0

Table 4.37. Response to Questionnaire Statement 3

The student (undergraduate statistics) who responded with a '3' here came up to me at the end of the session and discussed with me a point in the program where he felt the way I had worded one of the statistical points had been unclear.

- *The software gave me the freedom to do what I wanted* (Questionnaire Statement 4)

	Response	Frequency
1	(Strongly Agree)	6
2	(Agree)	11
3	(Neutral)	3
4	(Disagree)	0
5	(Strongly Disagree)	0

Table 4.38. Response to Questionnaire Statement 4

4.3.6.2. Tendency Towards Social Motivation

As I have already said, the social student is perhaps the hardest to detect by this method partly because they are the hardest to motivate to learn in the one-to-one CAL environment. The following questionnaire item was designed to detect this tendency in the students.

- *I would have preferred to work through the module in a group, perhaps with time for group discussion of the ideas presented* (Questionnaire Statement 5)

	Response	Frequency
1	(Strongly Agree)	2
2	(Agree)	1
3	(Neutral)	9
4	(Disagree)	6
5	(Strongly Disagree)	2

Table 4.39. Response to Questionnaire Statement 5

In the next chapter, I will discuss how this result interacts with the tendencies towards social motivation as detected by the learning styles questionnaire.

Before recruiting the students, I became aware that if there was a good response, then the computer lab capacity might be exceeded. To cope with this, I added a question to the recruiting form asking the potential recruits if they would mind doing the test on their own at a later date if the lab was filled; if they would prefer the main session or if they would prefer to do it on their own.

It occurred to me later that the answer to this question might act in some way as an indicator of social motivation. However, only fourteen of the recruits answered the question. No-one asked to do it on their own. Around half said they would prefer the main session, and half said they didn't mind.

4.4. Observations Made as the Students Worked

I observed the students from a distance as they worked, while ensuring that I wasn't putting anyone off by looking over their shoulder. Several useful observations were made as I watched, and at the end, several students made comments of interest. The observations are presented below in no particular order.

There are, of course, many ways to interpret these observations, but some of them are in line with expected behaviours given e.g. the student's learning style. This will be discussed more fully in the next chapter.

4.4.1. Observations

My general impression was that everyone seemed quite engrossed in their work. This would make sense in the light of the results of the general questionnaire as set out in **Section 4.3.6.1.1**. Some students (e.g. **UM1, US3**) worked through without any discussion with neighbours. **UM1** came and left on his own. Others appeared to be working together (e.g. a group consisting of **US5, US6** and possibly one other) to the extent that there was regular discussion, and they all seemed to be on the same screen when I looked. A couple of students went through at great speed (e.g. **US3, UM7**), others appeared to be taking care to read each screen carefully (e.g. **PS1**). One or two students didn't appear to be greatly engrossed (e.g. **UM7**). One student (**US3**) finished quickly and proceeded to give advice to his immediate neighbours. One student was quite wary of the program and before signing up was unsure if she was a suitable candidate to take part in the test (**PS2**).

There were very few requests for help from any student as they worked through the software. In the introductory comments made before the students began working through the software, I had said that I would be on hand if they had any queries. There were only two such queries. In the first, **PS2** got stuck on a dialogue box and wasn't sure how to clear it. **US8** appeared to be repeating the 20-ampoule test a large number of times. When I went over she asked me if this was the end of the program, then suddenly remembered that she could go on to the next page.

4.4.2. Comments Made

Few students gave me any verbal feedback at all. There were, however, several interesting comments made. When I discussed the conscientious student's profile with **PS1**, describing how I would expect such a student to work through the software, he said "Yes, that's me!". I overheard **PS3** describing the experience to some undergraduates she was teaching as "great fun". When I discussed with **TO3** the linearity of her pagetrack despite the Mild Curious learning style, she said that she had been more curious about what to do on the pages than finding out where she could go. Discussing the results of the experiment with **TS1**, she said that she had deliberately spent more time exhausting the page activities because she had been asked specifically to test the program.

I offered each student the opportunity to see the results and their interpretation at a future date. So far, **UM8** is the only student to take me up on this.

4.5. The Mechanism Used to Compute the Results

To extract useful information from the raw data requires a lot of painstaking and detailed calculation. To remove the drudgery and the human error from this task, I spent a lot of time writing an analysis tool that fulfilled several functions. Firstly, it is a database that stores all of the data from the experiment. Secondly, it will take the raw data generated by each student and from it calculate more than thirty parameters which are used eventually to give the eighteen or so variables described in this chapter. It also drew the linetrack diagrams and added the legend to each one. Finally it is a tabulation tool which allows any two variables to be tabulated against each other. It will create averages of cell contents and sort them into numerical order. Finally, the table can be saved to file in a format that allows it to be converted quickly to a table in the word processor.

I am certain that the time taken to write this tool is time well spent as it increases the reliability and the speed of all calculations. The code that performed the calculations was double checked several times with test data and real data and the results correlated with the same results derived manually. No code was accepted until the correlation was consistently 100% between the two results.

4.6. Summary

I am looking to try to establish some kind of correlation between learning style and working mode. To do this, I needed to determine several facts for each student. Firstly, their dominant motivational style, as a measure of learning style. This was answered by the results of a learning styles questionnaire. Secondly, I needed to find out how they preferred to approach a piece of teaching software which imposed no working style on them. This was done as they worked through a short teaching module that recorded everything they did including the route taken and the page activites carried out. In addition, I attempted to assess each student's reaction to what they had done, so I gave them a general questionnaire to determine this.

There were certainly some differences in working style between students with different learning styles, but some interesting differences came to light when grouping the students into undergraduates, postgraduates and pilot testers. In the next chapter I will discuss these results in detail in order to try to understand the effects of learning style and other learner variables on the individual students' working styles.

CHAPTER 5

Discussion and Analysis

Having set out the results, we can now re-examine the original questions about possible links between learning style and working mode, and any other interesting insights that have arisen from this research. In this chapter, I will firstly discuss each of the sections outlined in the last chapter. Some of these results may turn out to be valuable in answering the basic questions, some may provide unforeseen insights and some will probably shed no light on the situation at all. Having done this, I will proceed by taking the meaningful information and try to see what patterns, if any, emerge from it.

5.1. Discussion of the Individual Variables

In this section, I will discuss each of the individual results set out in chapter 4 in the order in which they were presented. In each case, I will give a section reference to the table or diagram in chapter 4 which is being examined.

5.1.1. Learning Style Variables

Thinking of the distribution of the different learning styles as set out in **Table 4.3** [**Section 4.3.3.1**], it is interesting to note that most of the students who displayed a dominant learning style or styles were either conscientious or curious, with a small number of social students. There are no students with a dominant achiever style in the sample. However, there were three students who selected one achiever item from the learning styles questionnaire.

Another vital question must be asked. How much do questionnaires of the type given to the students reflect their real learning style? As discussed in Chapter 3 [**Section 3.4.1**] an interrogative procedure like a questionnaire that poses direct questions can produce distorted results. On the subject of questionnaire design, at least two students (**TS1** and **TO2**) said that for at least one of the learning styles questionnaire categories there were two answers that they felt applied equally. This is an indication of the fact that there may be some error built into the questionnaire results as a result of the way in which students were forced to select one from four possibles.

However, the learning styles profile produced from the students' responses in the questionnaire is only a guide. A more accurate measure could be taken by increasing the number of questions in the questionnaire and using at least one other method to allow comparison.

5.1.2. Working Mode Variables

Table 4.4 [Section 4.3.4.1.1] indicates that there seems to be a pattern in the choice of initial working mode made by those with different learning styles. Twelve of the fourteen Strong and Mild Conscientious students chose "Step-By-Step Guide" (SBS) Mode. All three Strong Curious students chose "Work in My Own Way" (WIMOW). The Mild Curious students tended to choose SBS mode initially. This is partly explained by noting that three of the Mild Curious students were also Mild Conscientious.

One fact that seems independent of learning style is that almost without variation, the students spend most time in the mode they select initially. This can be seen by comparing **Table 4.4** with the results for the main working mode chosen as laid out in **Table 4.5 [Section 4.3.4.1.2]**. Because of this, I will simply discuss "Working Mode" without making separate reference to "Initial" and "Main" working modes.

As predicted, the conscientious students tended to choose the safer path offered by SBS mode, whereas those with curious tendencies, certainly with strongly curious designations are going for the less restrictive WIMOW mode. Most of the Mild Social students go for SBS also. Could this be a hint that a social tendency is more closely related to a conscientious one than to a curious tendency, at least with regard to the variable being measured here?

Looking at **Table 4.6 [Section 4.3.4.1.3]**, it is interesting to note that only one working mode change was made by a conscientious student, whereas there is a higher incidence of working mode changes amongst the curious students. This again might be predicted, since it is quite possible that the curious student will want to explore both working modes. Thus, the fact that the curious student spends time in SBS mode probably reflects a desire to investigate it, and is not an indication of a desire to be led through in the same way as the conscientious students would. However, although this is the predicted pattern, the numbers involved are small. Although there is a higher incidence of curiosity amongst the pilot testers, it could be that these working mode changes were made as part of their testing, though they were not specifically instructed to change the working mode.

It is clear from this table that the incidence of working mode changes is small. This goes along with the idea that the majority of students prefer to remain in the mode they initially select (an idea gained initially by comparing **Table 4.4** and **4.5**.)

5.1.3. Navigational Variables

5.1.3.1. Linearity

The screens in the test program can be viewed in any order i.e. it is possible to navigate around the module visiting the screens without any order restriction. There is a logical flow from start to finish, but other paths can be taken in which the order of presentation makes equally good sense. The two Working Modes give the student a choice between free navigation and a more structured presentation. Thus we can reasonably assume that the vast majority of the students were able to find a navigational style that suited them.

It is vital that the students chose to work the way they did without unnecessary imposition by the program, as the making a "natural" choice will throw more light on the students' motivational drives than their behaviour in a less flexible system would. This principle applies to all of the results generated.

Linetrack Diagrams

We now come to the linetrack diagrams. See **Section 4.3.4.2.1**. At first glance, the linearity and directness of the path taken through the program seems to be quite strongly linked to learning style.

Amongst those with Mild or Strong Conscientious learning styles, the path taken is much more linear and direct. The patterns of those with curious tendencies are, in general, much more non-linear and certainly less direct between start and finish. This is particularly true where the curious tendency does not coexist with a conscientious tendency. In general, the conscientious linetracks are much straighter, and on the diagram lie much more closely along the dotted line which indicates the most direct route, whereas the curious ones have a much more jagged appearance.

Again, as predicted, the conscientious students tend to follow the suggested path very closely. There is very little evidence of non-linearity in their patterns. As discussed in earlier chapters, this low-risk behaviour is characteristic of conscientious students.

On the other hand, those with strong curious tendencies exhibit a markedly greater level of exploratory behaviour as would be expected. The desire to satisfy curiosity is manifested by a tendency to make navigational decisions on the basis of curiosity and not out of a sense of obligation to follow the suggested track.

It is possible that the routes taken by the more curious students fall roughly into two classes. The first type is best described as non-linear. Student **TS2** (diagram in **Section 4.3.4.2.1**) took such a route which appears to be a mixture of short linear sequences and non-linear jumps (mostly via the map). The second type would be described as "linear, then non-linear". In other words, the student navigates initially like a conscientious student, following the linear path from start to finish, then he begins jumping around in a much more exploratory fashion. The patterns produced by students **PS3** and **PS4** most strongly typify this behaviour.

Percentage of Non-Sequential Jumps

A fascinating insight can be gained from looking at **Table 4.7 [Section 4.3.4.2.1]**. The fact that jumps out immediately is that no conscientious student made a single non-sequential page jump. In other words, all their jumps were to logically connected pages. The strongly curious students show a higher incidence of non-sequential page jumps than the conscientious students. I feel that this measurement reinforces the belief that conscientious students exhibit low levels of risk-taking and a general preference for linear paths whereas the curious students, as a function of their exploratory mindset, are electing to take a much riskier and less linear route.

Again, it should be pointed out that it is not possible to make non-sequential jumps from the map screen while working in Step-By-Step (SBS) mode. This was intended to prevent students who chose this safer mode getting lost by accidentally clicking the map and ending up at a completely different area of the program. Laurillard suggests that not being able to find your way back to the previous screen is one of top ten student pet hates when working with CAL [7].

However, having designed the program this way, it is possible to visit the map while working in SBS mode with the express intention of jumping to another area of the program only to find it is not possible. Unfortunately, the program does not detect such attempts. However, I must point out that only four of the seventeen students who selected SBS mode accessed the map, so for the remaining thirteen, the above situation could not arise. Of the four who did, two accessed the map right at the end of their time in the program, so it is less likely they were intending to use the map in this way. It seems more likely that they got to the end and noticed a button they hadn't yet clicked, or that they were keen to gauge their progress. The other two did so in the middle of their route through, so they may have attempted to make a non-linear jump. Thus there may be a small error in this result, but the overall message remains unchanged.

Percentage Revisitation

According to **Table 4.8 [Section 4.3.4.2.1]**, there is also a much higher incidence of page revisitation amongst those with curious tendencies whereas the conscientious students revisit pages to a much lesser extent. We would suspect this from the other results discussed above. If a conscientious student discharges his sense of duty by completing all of the instructions on a page during the first visit, he might feel no need to return to it later. Of course, a revisitation can be made in order to refresh your memory about a particular point.

It is possible that the greater level of revisitation carried out by curious students may be accounted for if they tend to take more than one visit to complete a page. The curious urge may lead a student to explore other screens before exhausting a page if he is curious primarily about where to go in the program. Other curious students may not revisit pages so much if their curiosity is directed more to the activities on the pages.

Again, I should point out that there is one compulsory revisitation if the student ends up in the suite of three screens mentioned in **Section 4.3.4.2.1** whilst working is SBS mode. This is not so in WIMOW mode, as the student could move on via the map or the options buttons etc. Thus, this revisitation is avoidable. Hence any given result does not necessarily contain this error factor and thus it cannot simply be compensated for by subtracting some constant term from all results. Because of this uncertainty, I decided to leave these results as they were.

Furthermore, the effect of this error factor on any given result is greatest for those results involving the smallest number of page jumps and decreases as the total number of jumps increases. Thus, any correction would only serve to accentuate the pattern already visible from the uncorrected results. Hence, the overall pattern remains unchanged.

5.1.3.2. Percentage of Screens Visited

This variable, as set out in **Table 4.9 [Section 4.3.4.2.2]** does not show any significant difference at all for the different learning styles. The measurement was taken primarily to gauge how much of the module the students were covering. It is quite clear that this result yields us little useful information about the behaviour of those with different learning styles. It does show, however, that every student covered the vast majority of the screens in the module. Perhaps this gives some indication that all the students were quite motivated about what they were doing as they were not told at any point to try out all the screens.

5.1.3.3. Number of Map Accesses

Again, there seems to be a difference between the behaviour of the conscientious students and the curious students. The results in **Table 4.10 [Section 4.3.4.2.3]** indicate that only two map visits were made by conscientious students whereas up to eight map visits were made by the curious students. This result is already hinted at by the "Percentage of Non-Sequential Jumps" result as most non-sequential jumps would begin on the map page. In SBS mode, the map is accessed via a button labelled "Progress" and in WIMOW mode, via a button situated between the forward and back arrows (see sections **3.4.5.1** and **3.4.5.2**)

At no point are the students instructed to visit the map, since it is not compulsory for the completion of the module. I suspect that this may be a contributory factor in the lack of map visits made by conscientious students. On the other hand, as the map screen provides a means of making all possible page jumps, it makes sense that it will be used more by the curious students as they move around in a non-linear way.

5.1.4. Activity Variables

5.1.4.1. Percentage of Activities Completed

The results for this variable are set out in **Table 4.11 [Section 4.3.4.3.1]**. There seems to be little significant difference between the different learning styles for this result. In other words, each student tends to complete most of the activites on the pages visited. This is to be expected. The conscientious student will carry out activities because instructed to do so, whereas the more curious student will do them more as part of their own exploration. Beyond this, this variable does not yield much information.

5.1.4.2. Percentage of Total Buttons Clicked

Like the previous result, this one, set out in **Table 4.12 [Section 4.3.4.3.2]** does not show up any significant differences between the learning styles. No student clicked more than about 65% of all the buttons in the module. At first glance, the curious student might have been expected to click a greater percentage of buttons that the conscientious student. However, it must be remembered that a significant proportion of the buttons in the module are associated with questions. When the correct answer has been found, the student is less likely to go on to click all of the wrong answers. Thus, the timing of finding the correct answer influences this result.

Also, the student's proficiency with the subject matter also influences the number of attempts required to uncover the correct answer and therefore the number of answer buttons clicked. This variable was measured as it is conceivable that some strongly curious students may go round clicking everything in sight, but no such student took part in this experiment. For all of these reasons, this variable is not really of any use.

5.1.4.3. Percentage of Actions Repeated

There does seem to be a difference in this result, set out in **Table 4.13 [Section 4.3.4.3.3]** for the different learning styles. On average the curious students are repeating a greater proportion of the actions they carry out. The strongly curious students repeat twice as many actions than the strongly conscientious students. Although the differences are not great, they perhaps give some hint that a curious tendency leads to a greater degree of repetition presumably in order to make sure the page activity is fully explored. By contrast, the conscientious students are tending to repeat actions only when specifically instructed to do so. It is worth noting that some activities are more obviously repeatable than others e.g. carrying out the 20-ampoule test is worth repeating, whereas answering a question again is not once the correct answer has been found.

5.1.4.4. Percentage Repetition

This result is set out in **Table 4.14 [Section 4.3.4.3.4]**. It appears that there is no difference in the extent of repetition between the different learning styles. In retrospect, however, I realise that this is a misleading measurement as it gives no indication of the number of repeated actions - the true measure of the extent of repetition.

5.1.4.5. Number of Repeated Actions

According to this result, shown in **Table 4.15 [Section 4.3.4.3.5]**, there is quite a clear difference between the different learning styles with respect to the extent to which page activities were repeated. Clearly, the curious students are repeating activites much more than the conscientious students. Again, this fits with the predicted behaviour - the curious students are repeating the page activites much more by dint of their exploratory mindset, whereas the conscientious students are only repeating activities insofar as they feel obliged to do so.

5.1.4.6. Completion of Interactive Areas

5.1.4.6.1. Changed Experiment Parameters

Refer to **Table 4.16 [Section 4.3.4.3.6]**. Students are not specifically instructed to change the experiment parameters, though they are made aware that it is possible. The first thing to note is that eight of the twelve conscientious students did not change the experimental parameters. This is to be expected, again because they are not required to change them. Several of the curious students did not do it either, though again, three of the Mild Curious students also have Mild Conscientious tendencies. The strong curious student who did not change the experimental parameters was the one least familiar with both computers and statistics, and thus may have chosen not to pursue the experiment further because of unfamiliarity with the context. This student (**TO2**) is discussed more fully in **Section 5.2.1.2.2**.

5.1.4.6.2. Graph Interpolation

This result, shown in **Table 4.17 [Section 4.3.4.3.6]**, does not really say much about the different learning styles, as almost all of the students interpolated along the graph. This time, the students were instructed to carry out the activity in question, so it makes sense that a greater proportion of students did. Notice that this time, ten out of the twelve conscientious students carried it out.

It is interesting to note the effect of giving a specific instruction on the likelihood of students with the different learning styles carrying it out. This result, together with the previous one may indicate that conscientious students are more likely to carry out activites if asked to do so.

5.1.4.7. Number of Test Questions Answered

There would appear to be no significant difference between the average number of test questions answered by those with the different learning styles, although the Mild Cur average would seem to be slightly lower than the others. See **Table 4.18 [Section 4.3.4.3.6]**. It is also interesting to note that every student answered either all of the questions or none of them. It might have been expected that the achiever students took the test more often than the social students, who dislike being tested, but these data do not allow this hypothesis to be tested. This variable does not yield much useful information in this experiment.

5.1.5. Other Variables

5.1.5.1. Total Time Spent in Module

Please refer to **Table 4.19 [Section 4.3.4.4.1]**. On average, the strongly curious students spent six minutes longer in the module than students of any other learning style, who spent on average about twenty minutes in the module. This would be expected as the curious students seem to spend more time exploring the module, have a higher rate of page revisitation and on average repeat activites more, as discussed in previous sections. Again, the numbers involved are small, so a difference in average of six minutes may not be a greatly significant one.

Bear in mind also that the program is relatively short, so this time difference may be accentuated for a longer module. There may be some social pressure for individual students to finish if they are taking longer than others. Seeing others leaving can sometimes cause people to finish a task prematurely. Because of this, some students may have spent less time in the module than they would really have liked. It is very difficult to test for this, except possibly by adding a question to the general questionnaire.

5.1.5.2. Number of Requests for Help

I expected that the conscientious or achiever students might ask for help more often than e.g. the curious students. However, as the results in **Table 4.20 [Section 4.3.4.4.2]** show, few requests were made for help. The result discussed in **Section 5.1.7.1.2** suggests that this is largely because the screen instructions were sufficiently clear that help was seldom required. The fact that the curious students are asking for help more often probably indicated that they are simply curious about the help feature, and does not usually indicate that they need or desire help. It is also interesting to note that several of the students who requested help did so right at the end of their journey through the program. Again, this may indicate that they were curious about the help button, as it was a button they hadn't clicked up to that point.

It doesn't necessarily make sense to suggest that conscientious students would request help more often. A high frequency of help requests may say more about the poor instructional design or unclear instructions in a program than about the student. However, in a piece of CAL material that didn't have an obvious sequence to it, help requests may have been more frequent despite clear instructions as the conscientious students sought guidance regarding which route to take. For these reasons, this variable is probably not much help in defining the difference between the behaviour of the different learning styles in this study.

5.1.6. Differences Between the Subgroups

I will now discuss the results categorised by subgroup. To recap, there are three subgroups; undergraduates, postgraduates and pilot testers. I should also mention again that only three of the five pilot testers were asked to **test** the program. The other two volunteered to have a go at the program. Thus, the label "pilot tester" is used quite loosely.

5.1.6.1. Learning Style

The results for this comparison are shown in **Table 4.22 [Section 4.3.5.1]**. This is a very interesting result. The first striking feature is the concentration of conscientious students amongst the undergraduates, and the low incidence of conscientious tendencies amongst the postgraduates. Also interesting but largely circumstantial is the high level of curious motivation amongst the pilot testers i.e. I just happened to choose pilot testers who were curious. Again, three of the Mild Curious undergraduate students are also Mild Conscientious.

Now look at **Table 4.23 [Section 4.3.5.1]** which expresses this data in a different way, averaging the number of conscientious and curious items chosen from the learning styles questionnaire by those in the different subgroups. Compare the number of conscientious items chosen by the undergraduates with that chosen by the pilot testers and the postgraduates. Again, there is a considerably higher frequency of conscientious items chosen by the undergraduates, indicating a higher incidence of conscientious behaviour amongst them. Compare this with the number of curious items chosen by the different subgroups. The pilot testers particularly, but also the postgraduates are choosing an average number of curious items that indicates quite a strong curious tendency amongst them, whereas this average undergraduate exhibits only a weak curious tendency.

5.1.6.2. Working Mode

5.1.6.2.1. Main Working Mode

This result is set out in **Table 4.24 [Section 4.3.5.2.1]**. Again there is a very clear division between the different subgroups. The first point to note is the very high proportion of undergraduates selecting "Step-by-Step Guide" mode (SBS). It is interesting to note that the undergraduates who selected "Work in My Own Way" mode (WIMOW) subsequently behaved in a very similar way to those choosing SBS mode. Earlier results might suggest this pattern, as most undergraduates are conscientious and the conscientious students have been shown to play safe in most respects. Notice also that most of the pilot testers are choosing WIMOW mode. This would be expected as it allows the students more freedom to explore, and the pilot testers exhibit high levels of curious learning motivation.

5.1.6.2.2. Number of Working Mode Changes

This result, shown in **Table 4.25 [Section 4.3.5.2.2]** is also very interesting. It shows that only one undergraduate ventured to change working mode, whereas half of the non-undergraduates carried out this action. This probably reflects the fact that most of the students found that they were quite happy to remain in the mode they selected initially (SBS for most undergraduates). The higher incidence of changes amongst the pilot testers partly reflects the higher incidence of curious behaviour amongst them, but may also have occurred as part of their testing of the program. I suspect that the presence of working mode changes indicates curiosity more than its absence suggests a conscientious tendency.

5.1.6.3. Navigation

5.1.6.3.1. Linetracks

Refer again to the linetrack diagrams in **Section 4.3.4.2.1**. There is a clear division in the patterns produced by those in the different subgroups. The most obvious comment is that almost without exception, the undergraduate linetracks are very straight, indicating a direct linear path from start to finish with few deviations. This fits with the high incidence of conscientious behaviour in the undergraduates. The one possible exception to this pattern is **UM1** (Mild Soc, but chose one Curious item also) whose linetrack shows a map visit and some page revisitation. In fact, this may even be one of the "straight through and then jump about" pattern suggested earlier for some of the curious students (**section 5.1.3.1; subsection "Linetracks"**). Perhaps this is a rare example of curious behaviour by an undergraduate in this study.

By sharp contrast, there are a significant number of linetracks amongst the postgraduates and pilot testers that exhibit non-linear behaviour - some a great deal, and some not so much. This ties in with the fact that the most common dominant style amongst these two subgroups is Curious, both Mild and Strong. The most extreme example is the pattern produced by **TS2**, which is highly non-linear, though it does perhaps proceed in a very roundabout way from start to finish. Note also that **TS2** picked all four Curious items from the learning styles questionnaire, indicating an unusually strong curious drive.

5.1.6.3.2. Percentage of Non-Sequential Jumps

This result, set out in **Table 4.26 [Section 4.3.5.3.2]**, is very striking. Not a single non-sequential jump was made by any undergraduate student. This kind of result could be guessed from the linearity of the undergraduate pagetrack diagrams. Again, I should point out that in SBS mode (which nearly all undergraduates selected), the map cannot be used to make non-linear jumps, but also that only a very small number of map visits were made by the undergraduates as a whole, so this barrier would not be encounter by the vast majority of the undergraduate students. This point is discussed in **Section 5.1.3.1; subsection "Percentage of non-Sequential Jumps"**).

By sharp contrast, the pilot testers are making a significant number of non-sequential jumps. Bearing in mind the shape of the pilot testers' linetrack diagrams, this should come as no surprise. It is also expected because of the high incidence of curiosity they exhibit.

5.1.6.3.3. Percentage Revisitation

Table 4.27 [Section 4.3.5.3.3] sets out another result where there exists a significant difference in behaviour between the different subgroups. The pilot testers and postgraduates are revisiting pages around four times as much as the undergraduates. Again, this result is hinted at by earlier results, such as the shape of the linetracks produced by the individual students. A more linear pagetrack indicates less page revisitation, as revisiting a page introduces a kink. Since revisitation is not required for completion of the module, it makes sense that undergraduates, who are mostly conscientious, do this much less than the others. Perhaps some of the revisitation carried out by the pilot testers is attributable to their testing of the program, but again, revisitation is not strictly required for this purpose.

5.1.6.3.4. Number of Map Accesses

According to **Table 4.28 [Section 4.3.5.3.4]**, the pilot testers are making use of the map much more than the other students. Again, since most of the pilot testers are curious, they visit the map more as it provides a means of seeing the whole structure of the program and a means of jumping to any page. The fact that no non-sequential jumps were made by any undergraduate is a consequence of the fact that very few map visits were made by them.

5.1.6.4. Activities

5.1.6.4.1. Percentage of Actions Repeated

According to the results in **Table 4.29 [Section 4.3.5.4.1]**, there is some difference in the percentage of actions repeated by students in the different subgroups. The undergraduates are repeating actions less than those in the other two subgroups. Again, it is possible that some of the repetition carried out by the pilot testers is attributable to testing, but even still, it would seem that a more curious disposition, as exhibited by the pilot testers and to a lesser extent by the postgraduates, leads to a greater percentage of actions being repeated.

5.1.6.4.2. Number of Repeated Actions

Table 4.30 [Section 4.3.5.4.2] shows another clear result. The pilot testers are repeating activities to a much greater extent on average than the other subgroups. Even after making some adjustment for the fact that the pilot testers may have repeated more times in order to test an activity, a threefold difference is significant. The undergraduates are simply not getting involved in the module activities to the same degree as the pilot testers.

However, within the pilot testers, there is a spread of results. Three of the pilot testers have carried out many repetitions and two, very few. The student with 213 repetitions (**TO1**) said to me that she had been more curious about the page activites than about navigating round the module. This is reflected by quite the quite linear linetrack diagram she generated.

5.1.6.4.3. Changed Experiment Parameters

The most obvious comment to make about the results in **Table 4.31 [Section 4.3.5.4.3]** is that most of the undergraduates did not change the experimental parameters. This again reflects the high incidence of conscientious tendencies amongst them, since this activity is not required for the completion of the module. Most of the pilot testers did carry out this activity, some up to ten times, trying out a whole range of values. This is classic "What If?" curious behaviour - stretching the parameters as far as they can go.

5.1.6.5. Other Variables

5.1.6.5.1. Total Time Spent in the Module

The result in **Table 4.32 [Section 4.3.5.5.1]** indicates a clear difference in the average time spent by the different subgroups in the module. The undergraduate and postgraduate average times are very similar, but the pilot testers spend between on average ten and eleven minutes longer. In at least one case this is due to the tester taking time to test the module. It could also be that the greater curiosity of the pilot testers causes them to spend more time exhausting the module's possibilities.

5.1.6.5.2. Number of Requests for Help

When examining **Table 4.33 [Section 4.3.5.5.2]**, it may seem that the pilot testers required more help than the other students. However, this is probably explicable by their testing the help facility, and also by their greater curiosity about the contents of the help facility at any given point in the program. The low incidence of requests for help again reflects the fact that most students found the page instructions sufficiently clear (see **section 5.1.5.2**).

5.1.7. General Facts

5.1.7.1. Level of Learning Motivation

5.1.7.1.1. Overall Reaction to the Software

- *I enjoyed working through the module*

The results in **Table 4.34 [Section 4.3.6.1.1**] suggest that every student enjoyed the experience of working through the module.

- *I would welcome computer-based material of this type as part of my course*

Again, from the results in **Table 4.35 [Section 4.3.6.1.1**] seems clear that the students experienced a positive reaction to the software. It was interesting to note that I made a throwaway remark to some of the students as they left the room that it must have been great working through a piece of software without having to compile a lab report afterwards. They agreed wryly with this comment. Perhaps in their subconscious, some students were more positive about the experience than they would have been if a report was required of them. Even still, it is a strong result.

5.1.7.1.2. Specific Reactions to the Software

- *I found the software easy to use*

The result set out in **Table 4.36 [Section 4.3.6.1.2**] is very clear: the students didn't have much difficulty operating the software. I was aiming to create a piece of software that was operationally transparent i.e. the student could concentrate on doing **what** they wanted without constantly getting hung up on **how** to do it. In terms of human-computer interaction, good CAL designs seek to minimize the fraction of time the user is occupied with "how".

- *The instructions on each page were clear - I always knew what to do next*

This is another clear result - refer to **Table 4.37** **[Section 4.3.6.1.2]**. It could be said that the instructions given on each screen were sufficiently clear that the students didn't require to ask for help. This is reflected in the frequency which the students asked for help (**see section 5.1.5.2**).

- *The software gave me the freedom to do what I wanted*

This is an interesting result. See **Table 4.38** **[Section 4.3.6.1.2]**. Again, most students seemed to be happy about the opportunities to behave the way they wanted to.

Let us examine the three students who selected "3 - Neutral" for this question. They are students **UM7**, **US2** & **US7**. It would be interesting to find out what things these students wanted to do but found they could not.

UM7 has a Mild Conscientious/Mild Curious learning style. She appeared to be uninterested as she worked through, taking only twelve minutes to complete the module. She carried out the page activites with very little repetition. Is it possible that some aspect of the module design got in the way of this student's curious learning preference, and in doing so, that the module failed to elicit much learning motivation and thus led to a superficial treatment of the program? This has to be a possibility, though there are of course other potential explanations for the student's behaviour. It should be pointed out that this student found the software easy to use and enjoyed working through the module. **US2** has a Mild Conscientious designation. His behaviour in the module was much more average - took about twenty minutes to work through, took a greater part in the screen activities and so on. **US7** has a Mild Social designation. She is quite average in most respects. So, there is no obvious pattern amongst those who responded with "3" to this question.

On the whole, it seems quite clear that the general level of interest and/or enthusiasm was high. Add to this the facts that all the students took part voluntarily and that the subject matter dealt with was, for most students, very close to their own studies. Therefore, it seems reasonable to assume that there was a good level of learning motivation amongst the group. This is vital, as it is only under such circumstances that a student will show his true learning style i.e. the behaviour demonstrated in the program has something to do with learning.

5.1.7.2. Tendency Towards Social Motivation

This is a fascinating result. Please refer to **Table 4.39** **[Section 4.3.6.2]**. This question is of a different type to the others. The other five questions in the questionnaire deal with various aspects of learning motivation in a more general sense. This question is an attempt to shed some light on the issue of social motivation. Only this question produced '4' and '5' responses (i.e. disagree and strongly disagree resp.). In fact the group is quite spread across the five responses. Three of the group said they would have preferred working in a group. Nine were neutral. Eight said they would not have preferred working in a group.

Obviously there are many possible reasons why the students gave the answers they did. However, it is also possible that the desire for a more social working mode as expressed in the answer given to this question may be an indicator of a social component in the student's learning style. In the same way, a student indicating a dislike for social interaction during this exercise may indicate an achiever or curious disposition. I will now discuss these separately.

5.1.7.2.1. Those Preferring Not to Work in a Group

It is interesting to note that both of the students (**US3, US4**) who chose '5' (Strongly Disagree) for this question also selected an 'Achiever' item from the learning styles questionnaire. The only other 'Achiever' item was chosen by a student (**US1**) who selected '4' (Disagree) for this question. This may reinforce the hypothesis that students with an achiever tendency express a dislike for group learning.

The other '4's were chosen by **PS4** (Strong Cur), **UM5** (Cur/Con), **UM7** (Cur/Con), **UM8** (Mild Soc), **US2** (Mild Con). The latter two chose one Curious item each from the learning styles questionnaire i.e. the Curious tendency is also well-represented amongst this group. All those mentioned above chose at least one Curious item; some chose two Curious items, and one individual chose three Curious items. This may suggest, in line with predictions, that the presence of a curious tendency may be accompanied by a dislike for group learning.

The odd result is **US2**, who despite showing a Mild Social tendency, said he would not have preferred to work in a group. However, he has only a mild social leaning, and mildly disagreed with the questionnaire statement. On this basis, this would not be considered a strong result.

5.1.7.2.2. Those Preferring to Work in a Group

Only three students said they would have preferred to work as part of a group. The student (**PS1**) responding with a '2' (Agree) is a Strong Cur, and did not select any Social items from the learning styles test. The other two students responded with a '1' (Strongly Agree). The first of these (**PS2**) shows a Mild Curious tendency, but only selected one Social item from the learning styles questionnaire. The second (**UM1**) is

Mild Curious, and again, only selected one Social item from the learning styles questionnaire.

Clearly, there is more going on here than a simple link between a desire to have carried out this experiment in a group and the possession of a social learning motivation. If these results suggest any linkage, it is between the dislike for group work and an achiever learning style, perhaps even a curious learning style. There seems to be no significant correlation here between the preference for group learning and the incidence of a social component in learning style. Again, these are very tentative conclusions since the numbers involved are small.

5.2. Second Section - Patterns

Looking back over the spread of results set out and discussed here and in the previous chapter, it becomes clear that some results represent clear divisions in the group; others suggest interesting or unforeseen patterns, whereas others give a flat response. Some results are useful because they confirm our hypotheses, others in their refutation of them, and others because they show an existing hypothesis to be too simple. However, some of the results gathered are of little use because they do none of the above. In this section, then, I will attempt to bring together the useful results gathered by the experiment and see what patterns, if any, emerge from them.

As already discussed, there seem to be two major variables involved - learning style, and the "stage" the students are at i.e. undergraduate, postgraduate or pilot tester. I will deal with each of these separately now.

5.2.1. The Effect of Learning Style

Investigating the possible links between learning style and working style is the main goal of my research. To recap, working style reflects the way in which the student prefers to learn, and therefore acts as a indicator of how they are best taught.

Several of the results gathered suggest quite strongly that there is indeed a learning style effect on the way that each student chose to work through the program. These results occur across the different categories of result i.e. Working Mode, Navigation and Activity. Thus it would seem that describing the differences between learning styles requires reference to these different categories of activity within the test program.

Let us proceed by creating a simple profile of each of the learning styles in the group based on the results above.

5.2.1.1. The Conscientious Student

It seems when looking at the results gathered that the behaviour of the conscientious students in this experiment is the easiest to define, for two reasons. Firstly, there seems to be little variation in the way they used the software, and secondly, because there are more of them.

Again, it would be predicted that the conscientious student prefers to adopt a low-risk working style, choosing a working mode that allows the new material to be assimilated safely and according to the recommendations given by the program.

This can certainly be seen from the various measurements made. Almost without exception, the conscientious students chose the more structured "Step-By-Step Guide" mode. Regarding navigation, they took a very direct route through the program - start to finish, visiting most screens only once. This is obvious from an examination of the linetrack diagrams. Their route did not involve out-of-sequence jumps between pages. The amount of page revisitation was low. Map visits by this group were very rare. In terms of page activity, they carried out the activities required of them, but rarely proceeded to explore the activities fully. The percentage of activites repeated is lower than that of the curious students, as is the average number of repeated actions. Furthermore, they did not engage fully in the interactive areas of the program.

5.2.1.2. The Curious Student

5.2.1.2.1. Definition

It is more difficult to come up with a definition of curious behaviour using the data in this experiment than it was for the conscientious students, again for two reasons. Firstly, and most importantly, curiosity seems to have been expressed in a variety of ways in terms of working style. To accommodate this, a broader definition of curiosity is required. For this we would need more data than I have here (the second reason). However, there were some characteristics that appeared consistently in the curious students' data, particularly where there were Strong Curious tendencies. As already discussed, the curious students would be expected to take a much less structured approach to the program, preferring to explore and investigate their own ideas.

In this experiment, the curious students displayed on average a more exploratory, or high-risk working style. Many of the curious students chose the more open "Work in My Own Way" mode. In terms of navigation, their route taken through the program was much more non-linear. This is obvious from the much more jagged linetrack diagrams, higher incidence of non-linear page jumps and a higher level of page revisitation.

Regarding activities, there was a higher percentage of activites repeated, more repeated actions, and greater involvement in the interactive areas of the program.

The data might suggest that the characteristic features of the curious working style are more pronounced in students with the strongest curious motivational drives i.e. the non-linearity of the route taken; the number of revisitations; the level of involvement in the screen activites and so on increase as the strength of the curious tendency increases. This idea is suggested by comparing the results of some Mild Curious students who show typical curious behaviour with e.g. **TS2** who picked all four curious items from the learning styles questionnaire and whose dealings with the program are easily the most original and exploratory of the whole group, and **TS1** whose chose three curious items, and whose behaviour is somewhere between the two.

5.2.1.2.2. Interesting Cases

There are some instances of a curiou: individual generating results that look more like those associated with a conscientious student. I will examine some of these cases now.

US3 has a Mild Curious learning style (with one achiever item chosen also). He chose "Step-By-Step Guide" mode; produced a very linear linetrack diagram, made no non-sequential jumps, did not repeat activites much and so on. However, unlike most other undergraduates, he accessed the map, and tried out the help facility. So then, curious behaviour may have appeared at certain points. It could also be, that the achiever streak in his learning style dominated the curious tendency because the experiment was run in a lab, providing an opportunity for competitive learning. It could also be that he just wasn't motivated to learn by the module. However, watching him work, he appeared to be quite engrossed in what he was doing. Furthermore, he strongly agreed that he enjoyed working through the module.

PS2 also has a Mild Curious learning style. Again, like **US3**, she proceeded through the module in a style more readily associated with a conscientious student, perhaps even more so than **US3**. From comments she made before the test, and in communications with me in the days before she took part, this student seemed a bit wary about getting involved. I would say that this could well have affected the working style that she adopted i.e. it may partly account for her choice of working mode and linear path. Had she been more at ease, her results may have been different.

Like the above, **TO1** also possesses a Mild Curious tendency. In terms of navigation, this student exhibited a linear pattern typical of a conscientious student. However, in terms of participation in screen activities, she behaved with more curiosity, exhausting most of the screen activites she came across. In fact this student carried out one of the highest numbers of repetitions of screen activities of anyone in the test. She said afterwards that she had been curious about the activities presented, and not so much about where to go in the program.

UM5 and **UM7**, both Mild Curious (and Mild Conscientious), exhibited something akin to a conscientious working style. This is partly due to the presence of a Mild Conscientious tendency which on this occasion, seems to have dominated. For whatever reason, be it a failure by the program to engage their learning motivation or for some other reason, the curious component in their learning style didn't seem to show through. **UM7** was neutral with regard to whether or not the program had allowed her to do everything she wanted to do.

TO2 has a Strong Curious learning style. She took an unusual route through the program, being the only student to use the "Review" facility which allowed the student to review the screens in the module. Apart from this, her working style is quite similar to that of a conscientious student. However, being a politics student, her subject of study was the furthest from the subject matter dealt with by the program. I suspect that the main reason for the lack of exploratory behaviour was that she was simply unfamiliar with the subject material.

5.2.1.2.3. Further Comments on Curiosity

It seems, then, that for many of the students who have a Mild Curious learning style (particularly those who also have a conscientious tendency also), their behaviour is more typical of conscientious students. Is it that the student's real learning style is being masked by other factors? For example, in the case of an undergraduate student, they may adopt a different learning style (as so many undergraduates do) that is very conscientious i.e. "Tell me what I need to know for the exams"? Or is it that the learning styles questionnaire has not measured their learning style accurately enough - bear in mind that some students felt that two or more items in the same category were equally true? Unfortunately, there are insufficient data in this study to make a definite statement about this, though I have no real cause to doubt the learning styles questionnaire.

The unusual cases in this study only serve to highlight that the situation is undoubtedly more complex than the hypotheses on test here allow for, at least until the hypotheses are modified in the light of this new data. It seems, for example, that the role of a curious tendency in giving rise to a style of working is reasonably complex, particularly where it exists as a mild tendency alongside other motivational tendencies e.g. a conscientious leaning. It could be, for example, that a curious tendency is more prone to being overshadowed by other influences than e.g. a conscientious motivational tendency is.

It could also be that the fruits of a curious learning style are rewarded less (or at least perceived in advance as such) than those produced by the more plodding conscientious style. Put more crudely, students usually come to believe that better marks can be obtained by cramming your head full of facts only to regurgitate them unprocessed in examination essays than you do by presenting a more considered argument which shows original thinking. If this is accurate, then there implications for the methods of teaching and assessment in science education.

An obvious influence on curious behaviour is the level of proficiency a student has in the subject. If the subject matter is new, then the student will usually spend time becoming acquainted with the basics before beginning to branch out creatively and develop his or her own ideas. To do this, it is often easier to follow a structured presentation. Thus the learning style of a curious student in this situation will probably be more conscientious initially, but will become increasingly curious as familiarity with the subject develops. A novice simply doesn't know what questions to ask since he has no knowledge on which to base a question. Curiosity does not exist in a vacuum - it requires an object. It was for this reason that I developed a module whose subject matter would be familiar to the students.

Clearly, curious behaviour is a complex phenomenon, as its outworking in each case depends on the object of the individual's curiosity. In the case of this experiment, the nature of the curiosity experienced by each student is a function of the intellectual objects presented by the program. Thus, it may not be adequate simply to label a student as "curious". It is possible that this learning style has not been resolved into subtypes before since it is only in a CAL environment, with its unique learning opportunities, that the different subtypes can be resolved. A suggested division might produce subtypes such as **Cur$_N$** (curiosity inspired by **navigational structures**), **Cur$_A$** (curiosity inspired by complex **activities**)and **Cur$_{AN}$** (curiosity inspired by both).

5.2.1.3. The Social Student

As discussed in chapter 3, the hardest group of all to define are the social students. There were five students in the group who had a Mild Social tendency and none who had a Strong Social tendency. It would be expected that these students would exhibit a marked preference for group learning; a preference for group evaluation of their work, and a dislike for competitive learning situations.

The data gathered here neither support nor contradict this. Of the four Mild Social students who took the learning styles questionnaire, three answered "Neutral" for the item regarding a preference for doing the experiment in a group; one returned "Disagree".

I have said already that the social students may be the hardest to cater for by CAL material because it is most often one student per computer, and perhaps does not lend itself to group learning situations which are favoured by the social students. It would be expected in light of this that these students would tend not to enjoy the experience.

However, all of the social students who took the general questionnaire said that they enjoyed working through the module and that they would welcome it as part of their course. Bear in mind that the question says "as **part** of your course" i.e. not a whole computer-based course. Provided that the course offered sufficient opportunity for group interaction at other times, the social student may not mind working singly with the computer. Anyway, the students can meet and discuss their computer work afterwards if they want to. The conclusion may be that in general, the higher the proportion of computer-based work in a course, the less happy the social students will be. Alternatively, it may be that the social student may dislike CAL if it is perceived to be included at the expense of more social learning opportunities.

Working one-to-one does not exclude the possibility of group work. As I observed the students working, there were frequent discussions between the students, two of whom, **US6** and **US7**, are Mild Social. However, another Mild Social student, **UM1**, came, worked, and left alone and appeared to be content to do so.

Unlike the conscientious or the curious students for whom it is easier to predict a working style, since their preferred working style is defined very much in terms of the learning material itself and not the social context in which it is learned, a social learning motivation relates principally to the learning environment and not so much to the learning material. Because of this, it is difficult to know what to expect from socially motivated students in terms of working style. Perhaps their working style is determined more by the other strands in their learning style e.g. a Mild Curious/Mild Social student will exhibit curious behaviour. This is the case for student **TO1**. A Mild Conscientious/Mild Social student, by contrast, may display more conscientious behaviour, and so on.

Other than this, there are simply too few data to shed much more light on the situation regarding the social students.

5.2.1.4. The Achiever Student

According to the results of the learning styles questionnaire, the test group does not contain any achiever students. No student selected more than one achiever item from the learning styles questionnaire. However, there was some achiever tendency present in the group, although the learning styles questionnaire suggests it is a weak one. Those students selecting achiever items from the learning styles questionnaire did show some of the patterns associated with achiever students - a dislike for group learning, for example (according to the results of the general questionnaire). In addition, one of the three displayed what could be considered classic achiever behaviour - he rushed through, finishing first in the group and then proceeded to offer advice to those around him. It is possible that this is stronger evidence of an achiever streak than the learning styles questionnaire result would suggest. It is not difficult to imagine how an achiever tendency could affect learning style.

I suspect that certain of the learning styles have more to do with working style than others. In other words, some learning styles, such as conscientious, curious and achiever are more easily mapped onto working styles than others, i.e. social.

5.2.2. The Effect of Stage

Judging by the data gathered, it would seem that there is a second strong influence on the students' choice of working style. I have called this the "stage" i.e. what stage the students are at with their studies. In this regard, every student was either an undergraduate, a postgraduate or a pilot tester. As in the last section, I will attempt to build up a simple profile for these groups. I am most interested in the undergraduates and postgraduates. The label "pilot tester" does not imply any particular stage of study. Thus I don't intend to build up much of a profile for them, but some points arise from their results that are useful for comparative purposes.

5.2.2.1. The Undergraduates

5.2.2.1.1. Definition of Undergraduate Behaviour

Of the three subgroups in the test group, I am most interested in the undergraduates, since they will be exposed to the type of teaching material used in the experiment much more than those in the other subgroups.

The first thing to notice is the high incidence of conscientious tendencies amongst the undergraduates. The average number of conscientious learning styles questionnaire items chosen by the undergraduates was just under 2 compared to 1.25 for the postgraduates and 0.25 for the pilot testers. By contrast, they chose on average 1.19 curious items, compared with 2.00 for the postgraduates and 2.75 for the pilot testers. Would this level of conscientiousness exist in an undergraduate population where learning and assessment were much more tailored to the individual? The next noticeable thing is that fourteen of the sixteen undergraduates chose "Step-By-Step Guide" mode, the one that offers them a safer path through the program.

In terms of navigation, the undergraduates chose a very direct, linear path from start to finish, made no non-sequential jumps, seldom revisited pages, and made very few map visits. I was slightly surprised that there were so few map visits by the conscientious undergraduates who chose SBS mode (i.e. almost all of them), since the map gives an idea of progress, and in SBS mode is accessed via a button labelled "Progress". After all, conscientious students place great importance on evaluation of their work by the teacher. Is this the same as a computer-based teacher giving you an indication of progress? Perhaps the students don't perceive it that way. Also, most undergraduates did not participate fully in the interactive areas of the program, although in general they did what was required of them.

I find it difficult to believe that there is so little curiosity amongst the undergraduates. Surely the message coming from these results is not that undergraduates are rarely curious. I feel that it is more likely that much of the curiosity in these students is being suppressed or masked by stronger influences, for example the perceptions of what will be awarded the best marks in assessments. In the next and final chapter, I will discuss ways in which students can be encouraged to show their true learning colours.

5.2.2.1.2. An Alternative Viewpoint - The Perry Model

It is possible to think of this phenomenon in a different way. The conscientiousness evident in the undergraduate students can also be thought of as a developmental stage. This notion leads to the model of Intellectual Development first described by Perry in the 1950's and 1960's [**38**]. Perry describes a series of stages or so-called "positions" through which the student progresses. Each position represents a certain way of thinking, or, as Finster put it in his review of Perry's model, a "cognitive filter" through which the students understand their world.

I do not want to describe the model in detail here - a summary of the important ideas can be found in Finster [**38**]. However, there are certain key points contained in the model that are useful in explaining some of the observations made in this study. Of particular interest here are the ways in which students at different stages view knowledge and their own role and that of the instructor in the learning process.

In the early stages described in the model, the student sees the world through a dualistic lens i.e. right-wrong, good-bad. Knowledge is a collection of facts, and Truth is absolute. Students at these stages experience anxiety when confronted with ambiguity and paradox, in fact with any form of uncertainty. They are also uncomfortable when required to interpret facts. At this stage the instructor is seen as the source of knowledge and as such is considered the absolute authority. In turn the students consider themselves the recipients of this knowledge and will work hard accordingly [**38**]. This stage is sometimes referred to as "**Perry A**".

As the student makes progress through the different stages, these attitudes change and develop also. The further along you go, the more relative and contextual knowledge and truth are considered to be; the greater the tolerance for multiple views and uncertainty becomes. As the student begins to move in this direction, there is a loss of security in knowledge as the realisation of the frailty of the knowledge grows. However, the student is beginning to develop independent thinking patterns. This intermediate stage is otherwise called "**Perry B**". As the student progresses, the instructor comes to be seen more as a source of expertise; a guide or consultant. The student considers himself less as a sponge to soak up information only to return it unprocessed later, but more as an evaluator of information whose role it is to form his own judgements and opinions **[39]**. The most advanced stages of this model are often referred to as "**Perry C**"; a state in which the student has become comfortable with the notion that knowledge is often relative and contextual.

There is an expectation that students will develop along these lines as they continue in their education, becoming increasingly independent in their approach to learning.

In his original work, Perry found that the mean stage for freshmen in various classes at Harvard and Radcliffe was 2.4. If the Perry model applies to students in general, then a high level of conscientious behaviour amongst the undergraduates in this study could be seen as inevitable since it would be seen as typical of a developmental stage that they pass through en route to intellectual maturity.

It is also worth considering that the undergraduates' behaviour is partly explicable by a lack of confidence in a CAL environment due to little experience of the medium. In theory, this might partly account for the high number of undergraduates choosing the more structured working mode. However, there appears to be little difference between the microbiology undergraduates (whose course involves almost no computing) and the statistics undergraduates (whose course involves a lot of computing) in terms of working and learning styles. Some difference might have been expected if the amount of previous exposure to computers was a significant influence - those with more experience choosing on average a less structured working style. Furthermore, the low level of computer experience could not account for the high incidence of conscientious tendencies amongst the undergraduates, as learning style measurements made in this study did not depend on the computer in any way .

5.2.2.2. The Postgraduates

There is a higher incidence of curiosity and a lower incidence of conscientious behaviour amongst the postgraduates compared to the undergraduates. This may be due in part to self-selection - curiosity is often among the reasons for carrying out postgraduate research. It may also be relevant that there is no rigid assessment in a Ph.D. of the type encountered in an undergraduate degree. In terms of navigation, there is a higher incidence of exploratory behaviour amongst the postgraduates - less direct routes taken through the program and more page revisitation. In terms of the level of involvement in the page activities, there is no significant difference between the postgraduates and the undergraduates. However, with a sample of four, it is difficult to compile a clear picture of the postgraduate student, although I was never trying to make general statements about any postgraduate, simply about the ones that took part here. Again, the main interest is in the undergraduates.

In the studies mentioned in the previous section, Perry found that the mean stage score increased as the students progressed through college [**38**]. To extend the line of argument to postgraduates, what has been described as a higher incidence of curiosity could also be explained as a more advanced state of intellectual development - one in which they see themselves more as an explorer of knowledge rather than a mere recipient.

5.2.2.3. The Pilot Testers

As already stated, the high incidence of curiosity in the pilot testers has no significance in itself i.e. it just so happens that this particular group of individuals exhibit high levels of curiosity. Thus, the pilot testers contributed most to the experiment by giving me some curious results rather than by giving "pilot tester" results.

The pilot testers generated some results that are quite opposite to those of the undergraduates. For example, the average number of curious items chosen was 2.75, conscientious 0.25.

As a result of their curiosity, some of the routes taken by the pilot testers are highly non-linear. There was a high level of page revisitation and non-sequential page jumps. The number of map visits made clearly exceeds that of the other two subgroups. In some cases the page activites were very thoroughly explored. The total time spent in the module was over 50% greater than that of the undergraduates or postgraduates.

In the case of the pilot testers, there is clearly some adjustment to be made for those individuals (three of the five) who were asked to test the program. However, no guidance was given as to how to go about the testing. So the fact that a highly non-linear route was chosen is probably still significant. Another tester may have chosen to test the program by going through meticulously in a linear fashion.

5.2.2.4. General Comments

Overall it would seem that the stage the student is at has more effect on working style for the undergraduates than for those in the other subgroups. Undergraduates are taught in certain ways and as a consequence make certain decisions about how they think it best to learn. Thus, of all the three subgroups, the undergraduates may be the most constrained by their learning environment. If a student perceives that the best marks are awarded for essays full of facts rather than for critical analysis of these facts, then it is little wonder that curious tendencies are often masked. Thus, the incidence of curious tendencies may well be higher than normal science education teaching methods show up.

The important question, then, is how can students be encouraged to learn the way they want to? What environment must be provided to bring them out of their shells? I will discuss this in the final chapter.

5.2.3. The Correlation Between Learning Style and Stage

It seems clear that most of the undergraduates display conscientious behaviour and the postgraduates are tending to be more curious. Thus the group might be resolved roughly into conscientious undergraduates and curious postgraduates. The data support the former grouping more than the latter. If this broad generalisation is true, it is not surprising that discussing the results according to learning style bears a striking resemblance to discussing the results sorted by subgroup. It should be noted also that this study dealt only with science undergraduates - the data do not allow any conclusions to be drawn regarding those studying in other subject areas.

So what does this mean? What relation, if any, do these groupings bear to those in the general student population? Is the average science undergraduate a conscientious plodder? Possibly. This would certainly match my own recollections of the kind of learning that went on while I was an undergraduate science student.

It is important to note that we can only make statements about the learning style the students exhibited during the experiment, since learning style is not a static property, but is a function of personal psychological characteristics, the teaching method, the type of assessment, social factors and so on. Thus we have to be careful as the data gathered here are only a window through which to view the bigger picture, and are not themselves the complete picture. Put otherwise, I suspect that if we were to measure the students' learning styles in the absence of the pressures of assessment etc. (if such a thing were possible), the picture may well be different. But in a sense this would be of little use, as the long-term goal of this kind of research is to have some impact on real-life teaching situations with all their complex influences. Furthermore, learning style can only be measured when the student is learning. But more than this, a learning style exists only when there is something to learn and thus, it cannot be dealt with in a vacuum.

5.2.4. The Relative Influence of Learning Style and Stage

This has been discussed throughout the sections above. In summary, it is difficult to assess the relative influences of learning style and stage. We would have to imagine what the picture would be if only one of the two variables were present.

However, it is my impression, if I am justified in suspecting that there is more curiosity in the student population that these data suggest, that the student's real learning style (the one the student displays in a learning environment that allows them to learn in their preferred way) is somehow masked by stronger factors e.g. the mode of assessment, the style of teaching and so on. In other words, I suspect that "stage" is often the stronger of the two variables when it comes to determining a student's working style at any given moment. In other words, simply being an undergraduate may have a stronger influence on the student's learning style than being naturally curious does.

5.3. Final Conclusions

I carried out this piece of research because I wanted to know what effects, if any, learning style (i.e. motivational style) had on the way a student chose to work through a teaching program. The data gathered here suggest strongly that there is an effect, and one that seems to be mostly in line with predicted behaviour. Alongside this, however, it seems that there may well be other influences that cause the real learning style to be laid aside, causing students to change the way they approach their learning.

CHAPTER 6

Criticism and Implications of this Study;
Areas for Further Research

Now that the results have been set out, analysed and discussed, I would like, in this final chapter, to critically examine the experiment carried out and, with the benefit of hindsight, discuss how I would do things differently in the future. To extend this, I will then set out what I see to be the areas of research opened up by this experiment that merit further study. Finally, I will discuss the implications of this research, before making a few parting comments.

6.1. Criticism of Experimental Design

Obviously some of the comments made in this section are answered by making a suggestion about future research. Thus, many of the ideas below could also be considered as areas for further research.

6.1.1. Level of Interaction

Although the students clearly liked the program, I would like to have designed the program with even more interaction. This would hopefully draw the students further into the learning experience by creating an environment that they feel they can really manipulate in their own way. This would include designing optional areas of greater difficulty and challenge for the most able and curious students.

6.1.2. Level of Learning Gain

I would have liked to be able to assess with more certainty the learning gain made by each student as a result of using the program. In other words, some sort of evaluation. This was present in a very simple form, as the multiple choice test at the end of the program. However, it yielded insufficient data to be used for evaluatory purposes. Some might suggest a process of pre- and post-testing to estimate the learning gain. However, this approach carries a large margin of error and the results are open to a wide range of interpretations. Also, it is not clear what counts as evidence of learning. Neither is it well known how the concepts being taught can come to be understood. Because of this, it is unclear what the basis is for judging learning gain.

Clearly, deciding what kind of evaluation to carry out in order to meaningfully assess the extent of learning gain requires a lot of careful thought.

6.1.3. Learning Styles Measurement

I measured learning style in one way only i.e. via the learning styles questionnaire. In retrospect, I could have made more than one learning style measurement. Either the existing learning styles questionnaire could have been extended to include more questions, or it could have been redesigned to force people to choose one of four boxes, each containing all of the test items relating to one learning style. I could also have carried out two separate tests and correlated the results. Although the learning styles questionnaire that I used was very similar to the one used by Al-Naeme [**19**], mine could have been validated separately to ensure a good spread of results.

6.1.4. Presentation of Numerical Data

In retrospect, some of the variables might have been better expressed as numerical counts rather than as proportions or percentages as they were in chapter 4. This might apply to certain variables in this study e.g. Percentage Revisitation, which might have been better expressed as the number of revisitations. However, it is more likely that the use of a percentage has obscured information rather than creating strange artefacts. Thus, I could only improve the resolution of the results by using numerical counts. Also, I feel the general picture came through to a large extent from variables for which this would not be a problem e.g. the linetrack diagrams.

6.1.5. Other Comments

With regard to comments made earlier about the philosophy of information gathering, I hope that I got the right balance between asking directly and indirectly when seeking to gain all of the desired information. I could also have added more statements to the general questionnaire to get answers to some of the basic questions that were either asked indirectly, or not at all. One example might be "I prefer learning when the teacher or lecturer is in charge of what I learn" or something similar.

There are several pieces of information that I gathered or generated that I did not use, in most cases because I felt that there was too much noise in the small dataset for that particular variable to merit spending time on it. Perhaps in a future rerun with more data, these variables could have been meaningfully included somehow in the spread of results.

I could perhaps have made more of the time aspects of the study e.g. the time spent on each screen. A list of the time spent the first time a student visited each of the screens was calculated, but it was not used. I could also have noted where in the pagetrack certain codes occurred e.g. Help requests. I did this for certain individual cases but not as a rule. This could have yielded some insights with more data.

6.2. Areas for Further Research

6.2.1. Gathering More Data

I would like to repeat the experiment with a much larger dataset e.g. 150 to 200 students to allow a more detailed study of the relationship between learning style and working style. I have mentioned that I didn't use detailed statistical techniques for data analysis because of the small sample size, but a dataset of 150 to 200 would certainly support such analysis.

6.2.2. More Student Input

I would also like the experimental process to involve discussions with the participants - this would allow them to describe how they felt about the program. I could then compare this with the theory and with their data. I would like to involve the students in designing the experiment by discussing with them issues such as the things they like to able to do in a CAL package; the things that frustrate them; the things they would find most helpful and so on.

6.2.3. Creating an Adaptive System

I said originally that I was aiming to design a program that took account of individual students' learning styles. This could be a software environment that tailors itself to the student's preferred way of learning. The title of this work reflects this. I proceeded to say that I had realised that this task could be broken down into at least two stages, the first of which was to uncover any links between learning style and working style in order to develop a model as the basis for such an adaptive learning system. It was this first stage that provided the objective for this study.

To take this forward, there is clearly a possibility that an adaptive system could be developed, after more work has been done to clarify the linkages between learning style and working style. This would be deliberately learner-centred and not computer-centred. In other words, it would be designed to contribute to learning first, and to the field of artificial intelligence second.

I would hope that the kind of discussions I proposed in the above section on Student Input would contribute significantly to the design of such a system. Apart from the obvious benefits of doing this, it would also help to keep the focus of the design on the learner.

6.2.4. Learning Styles at Different Stages

If Perry's research is anything to go by, then there is value in studying the distribution of the different learning styles and working styles at different undergraduate stages e.g. 1st year, Senior Honours. If the pattern repeated itself, then the tendency to think independently would increase with the stage the students were at. The results of such a study would have implications for course design.

6.2.5. Behaviour in a Non-Linear Environment

The teaching program I created had a sense of direction in it - a progression of ideas. However, some CAL software does not possess such a strong directional feel. I would like to try creating a teaching program of this latter type in order to observe the behaviour of students with different learning styles in this environment. I would be interested to see how the conscientious students fare - I predict that they would be the most likely to feel threatened by it. Generally it would be interesting to compare the behaviour of students with the different learning styles in a linear and a non-linear CAL environment. This study would hopefully widen our understanding of how learning style affects working style.

6.2.6. The Effect of Computer Experience

I would like to test the effect of computer experience on working style. This could be done by carrying out a trial in two groups, one of which was given some kind of introductory course on the basics of using the computer and operating the kind of software used in this study. If there proved to be an effect, then again there would be implications for module design.

6.2.7. The Role of Other Learner Characteristics

Having looked at motivational aspects of learning style, there is also much scope for studying the effects of different cognitive styles e.g. field independence, convergence/divergence on working style. I would hope that all research in this area will continue to advance our understanding the links between students' psychological makeup and their behaviour in a CAL environment.

6.2.8. Other Possibilities

It would be interesting, though not necessarily within the CAL field, to compare the proportions of the different learning styles found amongst the students in this experiment with those found in other studies. Are the proportions universal? Do they cross cultural and national barriers? This would indicate how portable the research done amongst UK students would be to those with other cultural backgrounds and *vice versa*.

It would also be interesting to investigate the effect of issuing direct instructions on students with different learning styles. Would the conscientious/achiever students be more likely to carry them out?

These are just a few of the possibilities for future investigation. Doubtless further reflection and rumination would produce many more.

6.3. Implications of This Research

It is hoped that this research and any other studies in this field might lead to refinements in teaching philosophy and methods. Students will certainly benefit from exposure to teaching material that tailors itself to their individual learning needs. If there are linkages between learning style and the way in which students prefer to work, as this study suggests, then CAL material should be designed accordingly. The outworking of this principle will vary in practice. However, in every case, each student should be able to work in a way that suits them.

I would hope that by using this kind of CAL that teaching staff can create courses that draw students out and encourage them to learn actively and interactively and not as spectators. After all the word "education" comes (according to some sources) from the Latin *e ducare* - to draw out. In science education, genuine learning must ultimately be more than the mere transmission of a body of knowledge. It must give rise to a certain frame of mind, one in which the student actively engages with the knowledge. As John Allen Paulos put it,

> "... what's important in science education is not the imparting of any particular set of facts ... but the development of a scientific habit of mind: How would I test that ? What's the evidence for it ? How does this relate to other facts and principles ?" [40]

The prevalence of conscientious behaviour, a "Perry A" attitude to learning, or whatever you wish to call it, amongst the undergraduate students in this study could indicate that such a drawing-out process is not occurring. If their experiences in and perceptions of learning situations are causing them to behave unnaturally in order to get by, then something is wrong. Something has to change. It comes down to a simple question - must the student change to accommodate the teaching or *vice versa*? Should we be seeking to change the way that people learn, or should we simply cater for the learning styles that people have, allowing Perry A's to remain at that stage while stretching only the more curious minds? Opinions will surely differ on this point. Personally, I would hold to the view expressed by Paulos above. Science education must teach people to adopt a method and not just a set of facts.

I am not sure how well a Perry A attitude to learning or strongly conscientious mindset lends itself to the scientific method. The conclusion perhaps is that we should seek to change the way people learn science only insofar as it is deemed necessary to allow them to develop a scientist's mindset, one of active curiosity, for themselves. If this is the case, what kind of learning environment must be created for students in order to coax them to engage in active learning? Certainly one that both encourages and empowers the student to participate in and interact with the science. The result of this research might be to begin to discern what factors need to be variable and which ones are neutral when seeking to create such an environment. Also, it is my hope that in future, the focus of CAL initiatives will not rest on the technology but on the learner. This is not a new message - many in educational circles seem to share this view. Perhaps by hinting at the extent of what may appear to be passive learning amongst science undergraduates, this study gives the old message new impetus.

Should this view appear to be one-sided, let me say that I am also conscious that all of this is taking place amidst dwindling budgets and soaring student populations. I hope that when all relevant factors are considered that some satisfactory way forward can be found.

6.4. Final Comments

This study has opened the lid on a largely unexplored area of educational research. The lack of research in this area is surprising, given the prevalence of CAL in UK higher education institutions. It is my hope that having prised it open a little more widely that further study and exploration will follow into what is undoubtedly a field of ever-increasing importance in higher education now, and will be for a long time to come.

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APPENDICES

Appendix 1: The Questionnaires

Appendix 2: The Test Program

Appendix 3: Variables and Other Data

APPENDIX 1

The Questionnaires

1.1. The Learning Styles Questionnaire

This was adapted from the test devised by Al-Naeme **[19]** whose test was given to secondary school children. I revised some of the items to put them in a university setting. The questionnaire is shown overleaf. The codes in brackets are the learning styles represented by each item in the test. These codes do not appear on the questionnaire that was given to the students, but are shown on the questionnaire here for reference.

Questionnaire shown overleaf

LEARNING STYLES

Enter your choice here (1,2,3, or 4)

	1	2	3	4	
About Class Work and Lectures	1 In lectures, I enjoy hearing about applications to everyday life, regardless of whether I will be tested on them or not. **(Cur)**	2 I don't like working alone when trying to learn new ideas **(Soc)**	3 I prefer being taught the facts rather than wasting time planning and carrying out investigations **(Ach)**	4 I don't like offering suggestions in class discussions unless I'm sure I'm right. **(Con)**	....
About Lab Work	1 I like practical work when the instructions are clear and I know just what I am expected to do **(Con)**	2 I enjoy discussing and doing lab experiments with my friends **(Soc)**	3 Lab practicals with rigid instructions bore me. I prefer lab sessions that allow me to follow my own ideas **(Cur)**	4 I hate doing practical work with other people since they can sometimes keep me back **(Ach)**	....
About Exams	1 I prefer being told exactly what I need to know for the exams rather than be left to find it out for myself **(Con)**	2 I prefer exam questions that give additional credit for evidence of original thought and extra reading **(Cur)**	3 It is very important to me to be in the top few in the class. **(Ach)**	4 The support of my friends is very important to me during exam time **(Soc)**	....
About Social Life	1 I'm normally so busy socialising that I tend to put off studying till the last minute. **(Soc)**	2 I prefer social and recreational activities in which I can compete with others and win. **(Ach)**	3 When exam time comes, I cut out other activities to concentrate on studying **(Con)**	4 I like to spend time pursuing new and unusual interests rather than stick to the usual ones. **(Cur)**	....

1.2. The General Questionnaire

QUESTIONNAIRE

Name:..

1) I enjoyed working through the module. (*Please circle a number*)

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	**2**	**3**	**4**	**5**

2) I found the software easy to use.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	**2**	**3**	**4**	**5**

3) The instructions given on each page were clear - I always knew what to do next.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	**2**	**3**	**4**	**5**

4) The software gave me the freedom to do what I wanted.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	**2**	**3**	**4**	**5**

5) I would have preferred to work through the module in a group, perhaps with time for group discussion of the ideas presented.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	**2**	**3**	**4**	**5**

6) I would welcome computer-based material of this type as part of my course.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	**2**	**3**	**4**	**5**

APPENDIX 2

The Test Program

2.1. Installation Information

Please read the sections on copyright and general information before installing the software. If you agree to abide by the terms stated, please proceed with the following instructions.

The program can be installed using the setup utility on the disk (in the pocket inside the cover). Insert Disk #1 (1 of 2) into the floppy disk drive and run "a:\setup" (if your floppy drive is "a"). Select a full installation from the options box. The setup utility will give you the option of creating a new Program Manager group with an icon.

Before you run the program, you will need to indicate which folder you wish the log file to be written to. The default is **"c:\~msc~"**. To change this, edit the configuration file **mscprog.cfg** in the folder containing all of the other installed files. This file contains a heading entitled "Working". Edit this line if you want to change the log file folder. For example, to change the folder to "c:\logdata", edit the line to become ...

```
Working = c:\logdata
```

2.2. Copyright Information

The test software ("software") and all accompanying documentation ("documentation") are protected by copyright. This means that you cannot take the whole program or a substantial part of it and claim authorship. The software is not public domain, freeware or shareware. The copyright also expressly forbids the use of the program, in full or in part, for financial gain, and also forbids unauthorized copying, decompiling or distribution.

However, the software can be used in a non profit-making research context to further the goals for which it was created, to further our understanding about the link between learning style and working style. I would be delighted if someone decided that the software could prove useful in this setting. The Author Level password is **bacon7385**.

The software is used at your own risk - your decision to take and use the software means that you fully accept all of the risks involved. While I believe the software to be free from fault, and am not aware that the software has caused any problems to date, I do not accept any responsibility for any damage, direct or indirect, arising from the use or misuse of the software. The software is included "as is" and no claim is made of its fitness for any given purpose.

2.3. General Information

The test program was written in Asymetrix ™ Toolbook™ version 3.0a. It will run on an IBM-compatible machine with the following minimum specification or greater: 386 processor (preferably with maths coprocessor installed), 4MB RAM, MSDOS 5.0, Windows 3.1, a VGA display (640x480 with 16 colours) and a mouse. Installation of the software requires 2.5 MB hard disk space and another 10K or so for data files generated at runtime.

2.4. The PageTrack Mechanism

The PageTrack mechanism was devised to log all student activity. It outputs a string of characters which represent the student's actions in the program. The string is updated upon completion of each action, and the updated string is written to a log file immediately to avoid data loss should the program crash for any reason. An extra safety feature was built into the log file system. When the program runs, it checks for the existence of a log file on disk. If it finds one, it uses a different filename for the new file. This is to avoid data loss if the program needs to be rerun for any reason e.g. power failure, while the student works through it. The log files are called **msclog?.dat** (? = an integer). A sample pagetrack output is shown below. The following output was generated by one of the student volunteers.

```
Pagetrack=abc[LD]+Ofgh11?i1j1111111111111111111132k1761lml2n3olp1qpqE
```

The characters comprising the output fall into three categories.

2.4.1. Pages Visited

These are represented by **letters**. Most are lower case, running from 'a' (title page) up to 'r' (multiple choice test at the end). There are two exceptions: 'O' for the options screen and 'M' for the map. The exact route taken can be determined by stripping out all the letters from the above string to give (see overleaf) ...

`abcOfghijklmlnolpqpq`

(page a > page b > page c > Options page etc.)

2.4.2. Page Activities

These are represented by **digits**. The screen activities are numbered according to the order in which the student is advised (though not obliged) to do them. For each page, there is a numerical value representing the highest activity number on that page. Using this information, we can tell if the page was completed, if certain activities were omitted or repeated, or were done in some other order than the one suggested.

2.4.3. Other Activities

These are represented by **special characters**, some of which appear in the sample above. These represent actions not relating to navigation or directly to the screen activities indicated by the numbers. A list of these is given below.

Code	Activity
?	Show help information (context sensitive).
$	Switch working mode.
[LD]	Step By Step Guide mode (i.e. LEAD me)
	Note that a '+' sign appearing directly after [LD] or [LV] indicates that the student asked to see the popup which indicates the function of each button at the foot of the screen. Likewise, a '-' indicates that they declined to see this information.
[LV]	Work in My Own Way mode (i.e. LEAVE me).
#	Jump to Options Screen.
<	Retrace Steps.

Table A2.1. Special codes used by the Pagetrack Mechanism

2.5. The TimeTrack Mechanism

The Timetrack mechanism records the number of seconds the student spent on each screen. This was done by starting a timer on page entry and stopping it on page exit. The difference is taken and the result is added to the end of the Timetrack log. I decided that it was inaccurate to measure the time elapsed between entering one page and entering the next, as some of that time may be a short delay caused by computer activity.

An actual timetrack log is shown below. The first value is quite high since the software was run before the students arrived in the lab. Thus, in all calculations, I replaced the initial value with one of 30 seconds, as this seemed to be the amount of time the students spent on the front screen.

```
Timetrack = 1165 48 112 31 15 33 64 101 98 268 138 14 13 5 9 15 17 60
29 8 25
```

2.6. Screen Shots

In this section a selection of screens from the test program are shown to give some idea of the type of teaching material that was created, and to give a flavour of the style of presentation used in the program used.

2.6.1. The Setup Screen

On this screen, the student selects one of the two working modes offered. In the picture below, the student has selected "Step-By-Step Guide" mode.

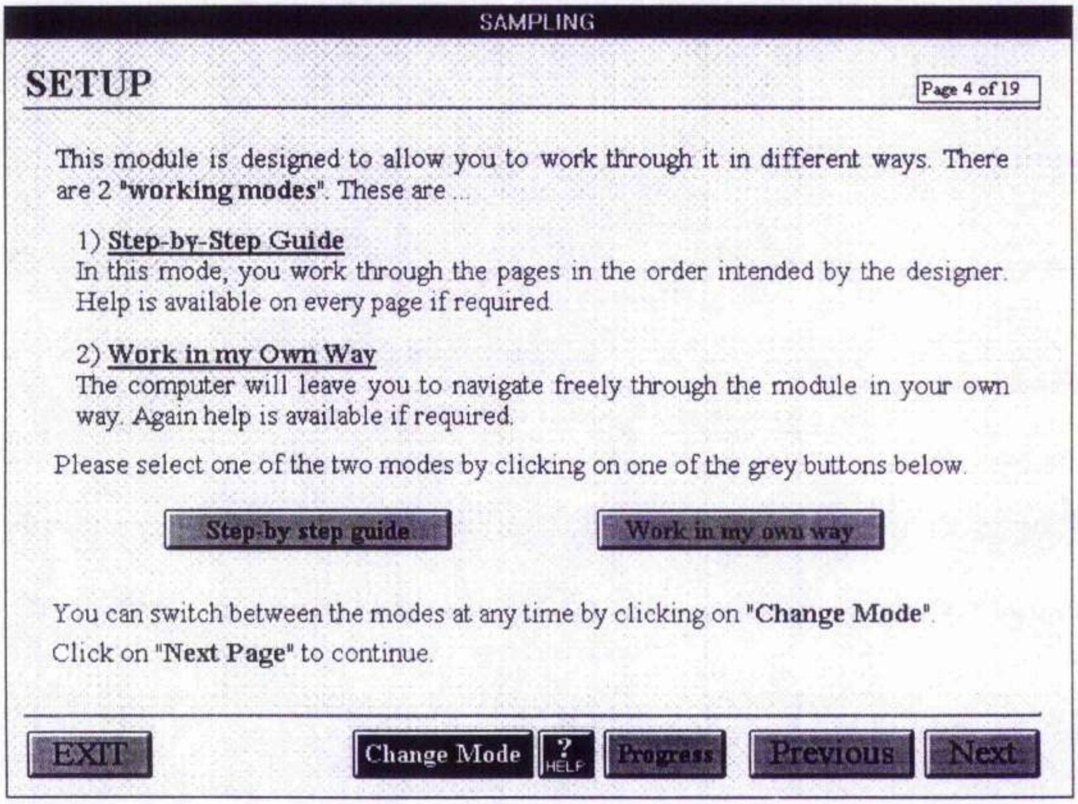

Diagram A2.1. The SETUP page

2.6.2. The Options Page

The student can jump to any section in the module from this screen (in "Work In My Own Way" mode). In "Step-By-Step Guide" (SBS) mode, the student will begin at the first section by clicking on "Next" (which is visible only in SBS mode).

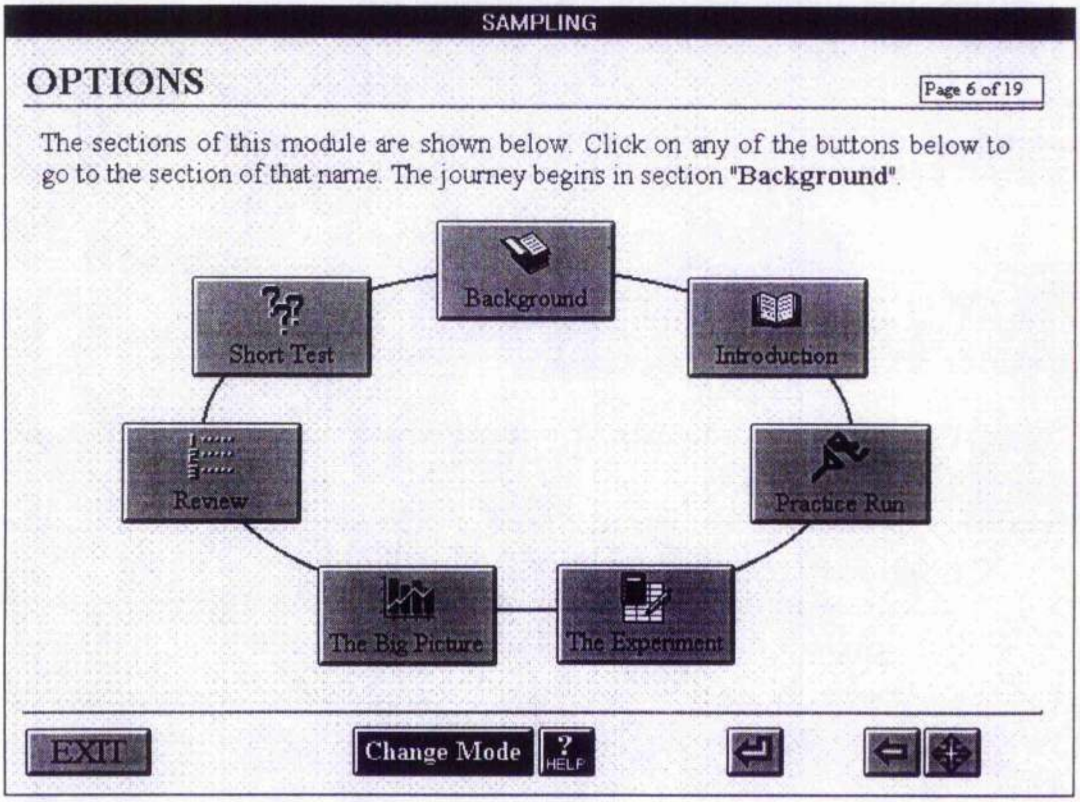

Diagram A2.2. The OPTIONS page

2.6.3. The Experiment

On this screen, the student carries out the 20-ampoule tests. After completing the first test, certain parameters can be altered e.g. contamination rate, and the test can be rerun with a fresh batch of ampoules.

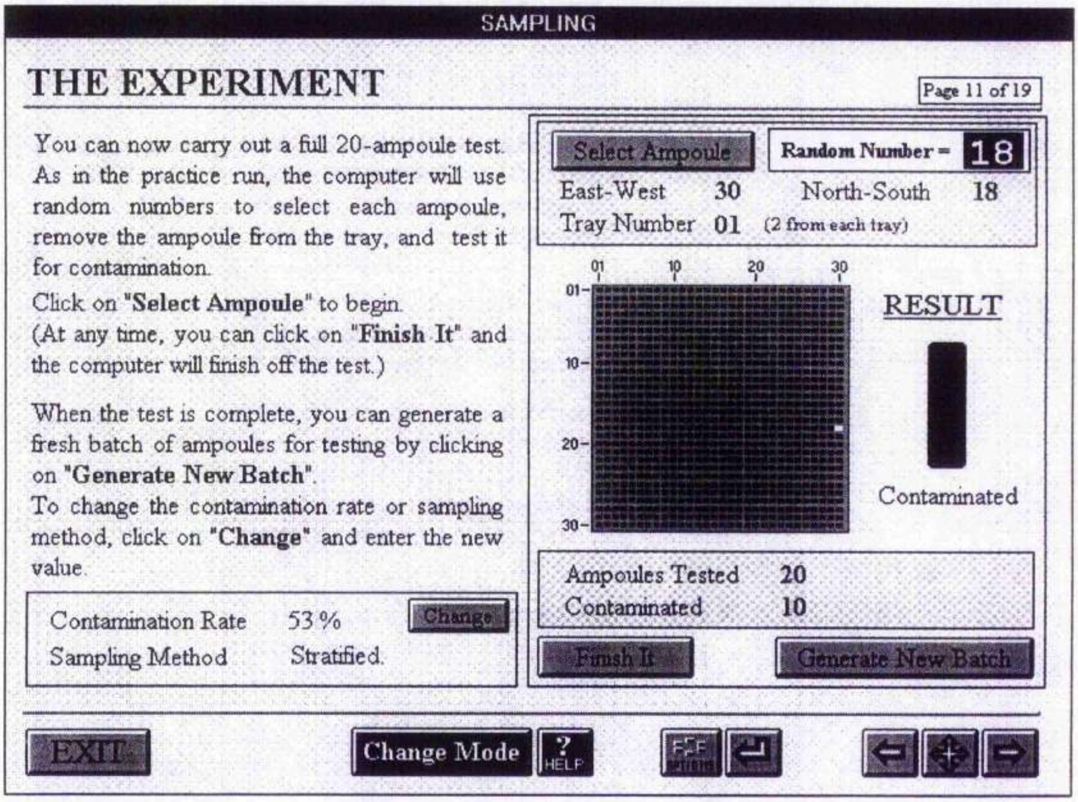

Diagram A2.3. The EXPERIMENT page.

2.6.4. Changing Contamination Rate

On this screen, the student investigates the relationship between contamination rate and the probability of detecting contamination.

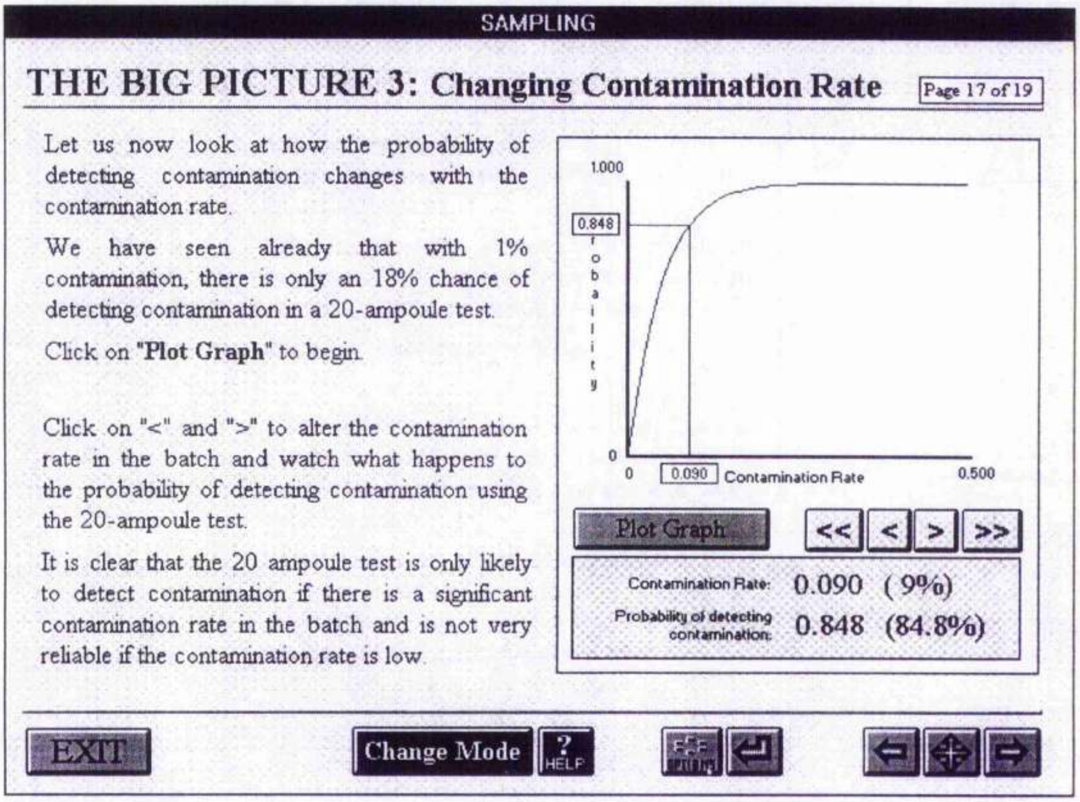

Diagram A2.4. THE BIG PICTURE 3 page

2.6.5. The Map Screen

In "Work in My Own Way" mode, this screen allows the student to navigate to any screen in the module and also acts as a progress indicator. In "Step-By-Step Guide" mode, this page acts only as a progress indicator.

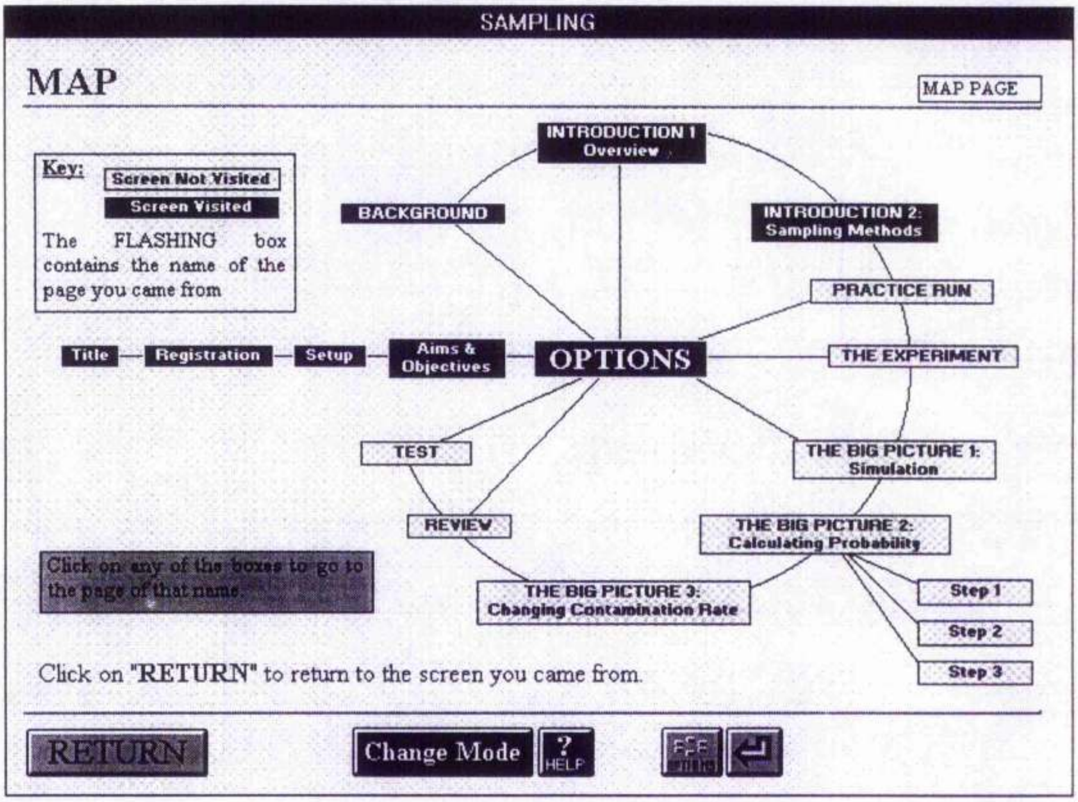

Diagram A2.5. The MAP page

APPENDIX 3

Variables and Other Data

3.1. Variables Calculated

Below is a table of all the variables used in this study. Each is accompanied by a brief comment. A fuller explanation and description of each can be found in the appropriate section in chapter 4.

Variable	Use	Description
Dominant Style	12	The student's dominant learning style as determined by the learning styles questionnaire.
Initial Working Mode	1-	The working mode that was selected when the student left the "SETUP" page (see **Diagram A2.1**).
Main Working Mode	12	The working mode that the student spent the most time in.
Changed Working Mode	12	The number of times the student changed working mode.
Percentage of Non-Sequential Jumps	12	The percentage of page jumps that took the student to a page out of sequence.
Percentage Revisitation	12	The percentage of page visits that were made to pages that had already been visited.
Percentage of Screens Visited	1-	The percentage of all the screens in the test program that were visited.
Number of Map Accesses	12	The number of visits to the map.
Percentage of Activites Completed	1-	The percentage of all the activities available on the visited screens that were completed.
Percentage of Total Buttons Clicked	1-	The percentage of the buttons in the module that were clicked, not counting the navigational and other buttons at the foot of the screen.
Percentage of Actions Repeated	12	The percentage of the actions the student carried out that they repeated later.
Number of Repeated Actions	12	The number of times the student carried out an action (individual mouseclick, and not an **activity** which may consist of more than one action) that they had carried out previously.

(continued)

Variable	Use	Description
Percentage Repetition	1-	The number of repeated actions (see previous entry) expressed as a percentage of the total number of actions carried out.
Changed Experiment Parameters	12	Whether or not the student changed the experimental parameters of the 20-ampoule test (see **Diagram A2.3**)
Graph Interpolation	1-	Whether or not the student interpolated along the graph in the Probability section of the program (see **Diagram A2.4**)
Number of Test Questions Answered	1-	The number of questions answered from the multiple choice test at the end of the program.
Total Time Spent in Module	12	The total time spent in the module.
Number of Help Requests	12	The number of times the built-in help facility was invoked.
Percentage of Correct Answers	- -	The number of correct answers as a percentage of the total number of answers given.

Table A3.1. Table of the all the variables used in this study. **Key**: Under "Use", **1** indicates that the variable was tabulated against learning style (i.e. dominant style); **2** indicates that it was tabulated against the different subgroups i.e. undergraduates, postgraduates etc.

3.2. Extra Results

This section contains all of the tables of data that were generated but not used and any other variables that were calculated but which ultimately were not used.

3.2.1. Extra Tables

- Table of the **Percentage of Correct Answers** against learning style. N/A indicates that the test was not taken by that student. Taking into consideration only the multiple-choice questions at the end, this variable was calculated simply by expressing the number of correct answers as a percentage of the total number of answers given i.e. 100 * correct / (correct + incorrect). See overleaf for table.

	Percentage of Correct Answers
Strong Con	75.0 85.7 N\A 83.3
Mild Con	85.7 N\A 85.7 71.4 85.7 83.3 100.0 N\A
Strong Cur	75.0 75.0 66.7
Mild Cur	N\A 85.7 71.4 N\A N\A 75.0 N\A 85.7
Mild Soc	71.4 71.4 100.0 83.3 N\A
No Pattern	83.3

Table A3.2. Table of the Percentage of Correct Answers against Learning Style

- Table of the Percentage of Correct Answers for the different subgroups.

	Percentage of Correct Answers
Undergraduates	71.4 85.7 75.0 85.7 N\A N\A 85.7 71.4 71.4 85.7 71.4 83.3 83.3 100.0 83.3 N\A
Postgraduates	83.3 N\A 75.0 75.0
Pilot Testers	N\A 75.0 85.7 66.7 N\A

Table A3.3. Table of the Percentage of Correct Answers for the different subgroups

- Table of Initial Working Mode for the different subgroups.

	Initial Working Mode	
	SBS	WIMOW
Undergraduates	14	2
Postgraduates	3	1
Pilot Testers	1	4

Table A3.4. Table of Initial Working Mode for the different subgroups

- Table of the Percentage of Screens Visited for the different subgroups.

	Percentage of Screens Visited	Average
Undergraduates	100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 94.4 94.4	99.3
Postgraduates	100.0 100.0 100.0 94.4	98.6
Pilot Testers	100.0 100.0 100.0 100.0 94.4	98.9

Table A3.5. Table of the Percentage of Screens Visited for the different subgroups

- Table of the Percentage of Activites Completed for the different subgroups.

	Percentage of Activities Completed	Average
Undergraduates	95.0 90.0 90.0 90.0 87.5 85.0 80.0 80.0 75.0 75.0 75.0 75.0 75.0 65.0 60.0 56.3	78.4
Postgraduates	95.0 85.0 80.0 68.8	82.2
Pilot Testers	90.0 90.0 87.5 80.0 70.0	83.5

Table A3.6. Table of the Percentage of Activities Completed for the different subgroups

- Table of the Percentage of Total Buttons Clicked for the different subgroups.

	Percentage of Total Buttons Clicked	Average
Undergraduates	63.3 60.0 60.0 60.0 56.7 53.3 53.3 50.0 50.0 50.0 50.0 50.0 46.7 43.3 40.0 30.0	51.0
Postgraduates	63.3 56.7 53.3 36.7	52.5
Pilot Testers	60.0 60.0 53.3 46.7 46.7	53.3

Table A3.7. Table of the Percentage of Total Buttons Clicked for the different subgroups

- Table of Percentage Repetition for the different subgroups.

	Percentage Repetition	Average
Undergraduates	90.4 85.6 79.3 77.5 74.2 68.9 68.5 66.7 66.1 64.5 63.3 62.7 61.0 54.1 40.0 38.2	66.3
Postgraduates	72.0 67.5 65.9 61.5	66.7
Pilot Testers	92.9 89.1 86.2 54.0 53.5	75.1

Table A3.8. Table of the Percentage Repetition for the different subgroups

- Table of Graph Interpolation for the different subgroups.

	Interpolated Along Graph ?	
	YES	NO
Undergraduates	14	2
Postgraduates	4	0
Pilot Testers	5	0

Table A3.9. Table of Graph Interpolation for the different subgroups

- Table of the Number of Test Questions Answered for the different subgroups.

	Number of Test Questions Answered	Average
Undergraduates	4 4 4 4 4 4 4 4 4 4 4 4 4 0 0 0	3.3
PostGraduates	4 4 4 0	3.0
Pilot Testers	4 4 4 0 0	2.4

Table A3.10. Table of the Number of Test Questions Answered for the different subgroups

3.2.2. Unused Variables

First Visit Times

By examining the pagetrack data and timetrack data, I extracted the time spent on each of the screens the first time the student visited them. This variable would have allowed me to investigate any differences in first visit times between the different learning styles. In retrospect, however, I was unsure of how I could use this information and what it might possibly mean, so I decided not to continue that line of inquiry.