An Evaluation of Factors Affecting Students' Use of a Web-based Engineering Resource

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Abstract

The introduction of Web-based resources to support learning and teaching in Higher education has prompted a plethora of research into their effectiveness. Of the studies that have examined the role of cognitive style and learning strategies, results have generally been rather inconclusive and contradictory.

The purpose of this work was to investigate the relationship between a number of influential factors, including cognitive style and approach to learning, and students' processing behaviour during their use of a particular Web-based resource for Electronics and Electrical Engineering undergraduates. This was achieved through the development of a learner profile for each student using Riding's (1991) Cognitive Styles Analysis test (CSA) and Biggs, Kember and Leung's (2001) Revised Study Process Questionnaire (R-SPQ-2F). The quantitative component of the research was then set against a detailed analysis of students' processing behaviour using verbal protocol data gathered through individual think-aloud sessions and post-intervention interviews.

The results of the quantitative component of the research provided no compelling evidence to suggest that cognitive style was a factor that influenced student performance while using the resource or their perceptions of the package. There was however some evidence to suggest that the package was more positively received by students' who profiled as deep learners than their surface counterparts.

The analysis of students' processing behaviour from their verbal protocols highlighted a number of the resource's shortcomings, which typically promoted a surface, goal-orientated approach to its content. It also identified problems with the design and structure of the resource, which at times had a deleterious effect on learning. The results also raised questions regarding the efficacy and use of psychometric inventories in this kind of research.

I DECLARE THAT THIS THESIS HAS BEEN COMPOSED BY MYSELF AND THAT THE WORK DESCRIBED IN IT IS MY OWN

BRIAN CANAVAN

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List of Abbreviations

ADSL	Asymmetric Digital Subscriber Line
C&IT	Communication and Information Technology
CAA	Computer Aided Assessment
CAI	Computer Aided Instruction
CAL	Computer Aided Learning
CBL	Computer Based Learning
CBT	Computer Based Training
CD ROM	Compact Disc – Read Only Memory
CMC	Computer Mediated Communication
CSA	Cognitive Styles Analysis
EDEC	Electronic Design Education Consortium
EEVL	Edinburgh Engineering Virtual Library
ELT	Evaluation of Learning Technologies
HCI	Human Computer Interaction
HTML	Hyper Text Markup Language
IBL	Internet Based Learning
ICT	Information and Communication Technology
ISO	International Standards Organisation
JISC	Joint Information Systems Committee
Kb	Kilobytes
Kbps	Kilobytes per Seconds
LTDI	Learning Technology Dissemination Initiative
LTM	Long-term Memory

Mb	Megabytes
Mbps	Megabytes per second
MLE	Managed Learning Environment
MP3	MPEG Audio Layer 3 (see MPEG)
MPEG	Moving Picture Experts Group
R-SPQ	Revised study Process Questionnaire
STM	Short-Term Memory
TILT	Teaching with Independent Learning Technologies
TLTP	Teaching and Leaning Technology Programme
VLE	Virtual Learning Environment
WBL	Web Based Learning

Chapter One

Background to the Research

1. Introduction

"There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialisation extends. The investigator is staggered by the findings and conclusions of thousands of other workers' conclusions which he [sic] cannot find time to grasp, much less to remember, as they appear. Yet specialisation becomes increasingly necessary for progress, and the effort to bridge between disciplines is correspondingly superficial." (Vannevar Bush, 1945).

With Bush's observation in mind, it is the responsibility of the researcher to develop an understanding of his or her research interest through interrogation of the literature with the intention of reaching some worthwhile conclusion. This must be achieved more than ever in the wider context of international research available from a myriad of sources. This thesis describes an evaluation of students' behaviour during their use of a particular multimedia resource for engineering undergraduates. It was developed by the Electronic Design Education Consortium (EDEC) which consisted of eight English universities and was funded through the *Teaching and Learning Through Technology Programme* (TLTP) created by the higher education funding councils. The EDEC package was originally developed for delivery via CD-Rom, but was subsequently repurposed for Web-based delivery due to a perceived market demand. The purpose of this research was to consider whether certain students were advantaged or disadvantaged by the method of delivery of the EDEC package and in particular through the use of animated media in relation to their identified cognitive style and approach to learning (deep or surface).

1.1. E-Learning and the Web

As the Worldwide Web has become part of our social fabric, so its exploitation as a delivery platform for education has increased. For many, there has been a tendency to enthusiastically embrace the idea of electronically delivered course material. Politicians see it as an inexpensive means of providing mass-market education (Dearing, 1997) while some educators view it as a cynically exploited source of funding which can offer greater benefit to the standing of institutions than the learning environment (Duderstadt, 1999). McAleese (1996) for example expressed concern at the use of learning technologies purely a means of increasing productivity and reducing costs through the replacement of teachers by machines. Over the last twenty years funding bodies have contributed millions of pounds towards the development of electronic teaching and learning resources, many of which now gather dust on academics shelves, irrespective of the validity of their content. While there have been a number of relatively high profile initiatives, both UK-wide and particular to Scottish education, Haywood et al (2000) indicated that awareness and therefore uptake among the academic community can be lower than perhaps expected. This can result in the use of learning technologies by individual academic enthusiasts without the support of strategic planning at faculty and institutional level for their effective integration (Maier, White and Barnett 1997).

The introduction of MIT's course materials to the Web with unlimited free access to all has perhaps dealt a mortal blow to those who had hoped to exploit the Web by offering expensive online materials to those who can afford them. While MIT's material is not credit bearing, their approach to revolutionising the opportunities that are available for learning is reminiscent of an earlier revolution, namely the introduction of printed media in the fifteenth century. Where this new revolution differs is in the manner of delivery of knowledge through the use of multimedia. It is now possible to produce an electronic 'document' which includes text, sound, video, static and animated media. Haptic devices are also becoming available to allow interaction with software through touch. Even smell can be delivered through devices that are linked to computers, with the intention of triggering memory. Future learning technologies may therefore allow interaction with every sensory input channel that humans possess. In the meantime however resources are generally limited to the use of predominantly visual media and the challenge for the resource developer is to incorporate these in a manner that does not undermine the process of learning.

Present transient limitations such as the speed and reliability of Internet connection will recede with time, although their effect on learning through Web-based resources cannot be dismissed so easily. For example, a resource developed to operate over a dial-up network operating at a Baud rate of 56Kb/sec may have built in limitations while a resource developed for high speed broadband connection may prohibit its use (Gloor et al, 1998). It is therefore necessary for educational resource developers to consider the use of multimedia in relation to hardware and software limitations at the outset of any project and strike the appropriate balance between effective resource use and longevity.

1.2. The EDEC Package

Although the EDEC package was selected for the research due to its use of multimedia, a number of shortcomings were observed during the initial evaluation which suggested that little, if any, rigorous evaluation of the package had taken place at the time of development. This was in spite of the wealth of literature which generally recognises the need for rigorous formative and summative evaluation of learning resources (Conole and Oliver, 1998; Doughty et al, 1995; Frechtling and Sharp, 1997; Laurillard, 1993; Oliver and Conole, 1998; George and Cowan, 1999; Kewell, Oliver & Conole, 1999; Scriven, 1980; Shadish, Cook and Leviton, 1991; Shaw, 1998). There are also a number of models of good practice that can be applied to the development of multimedia resources such as Royce's *'waterfall'* model (Marshal et al, 1997, Sandford, 1990, Bostock, 1998) and Boehm's *'spiral'* model (see Figures 1 and 2), although no philosophical model for the development of EDEC was evident beyond the notion of the repurposing of existing lecture materials.

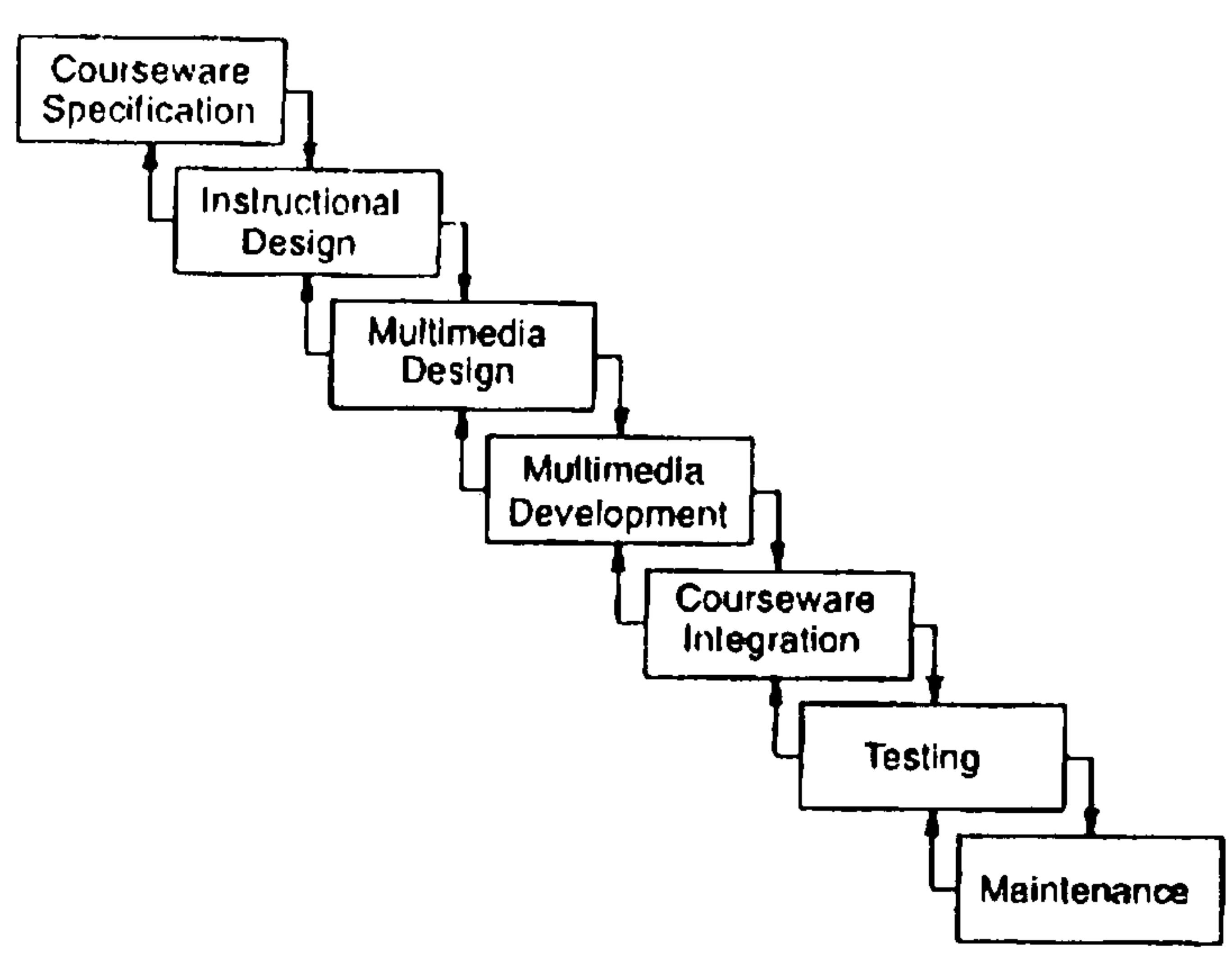


Figure 1 - Royce's Waterfall Model for Courseware Development

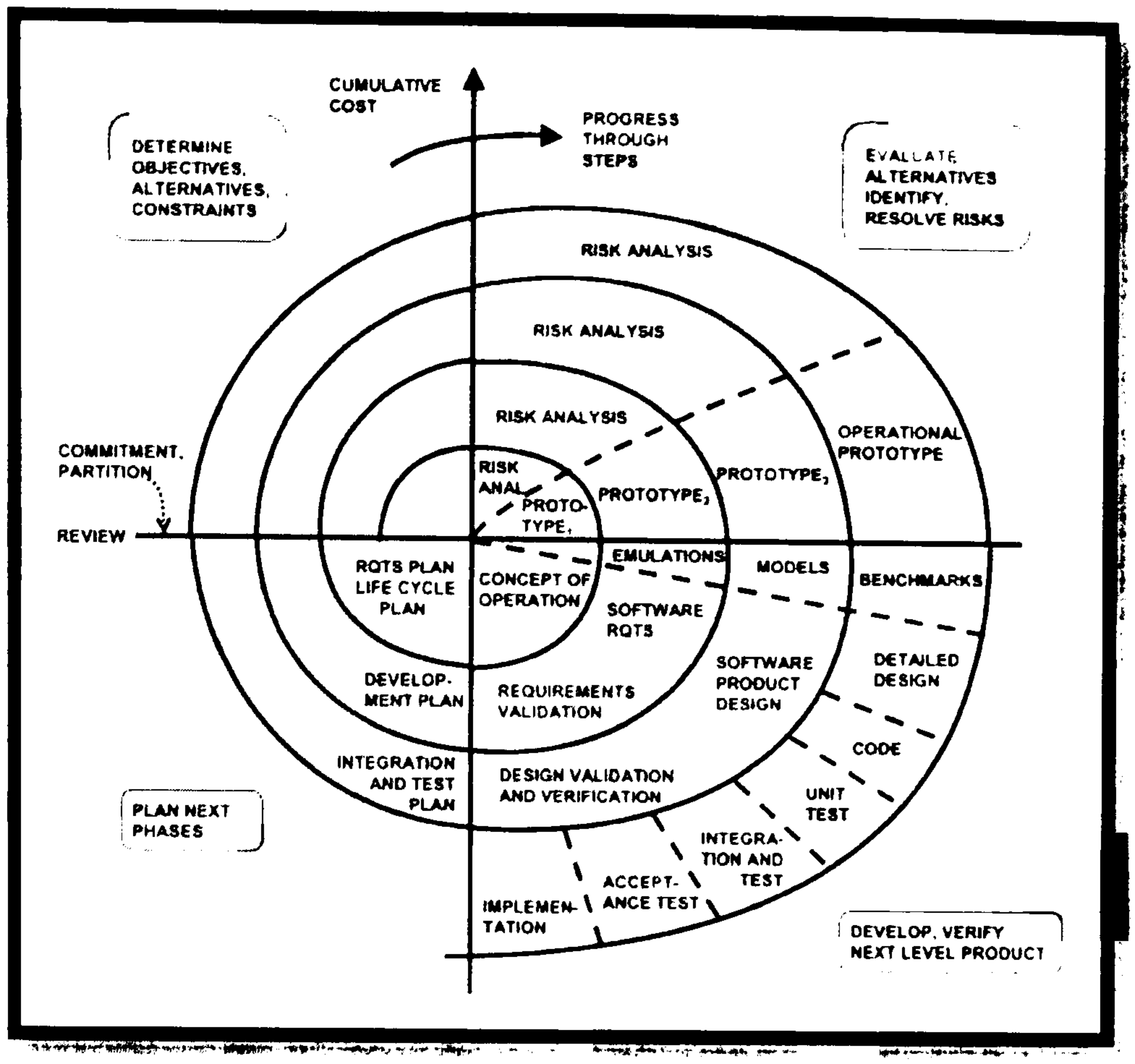


Figure 2 - Boehm's (1988) Model for Resource Development

While there is a general consensus towards the promotion of a user-centred approach to the development of computer and Web-based learning materials (Macleod, M, 1994, Bevan and Curson, 1997, 1999, Bevan, 1998, 1999) a clear lack of any substantial development philosophy became apparent during an early interview with one of the EDEC developers who suggested that an '*intuitive*' approach had been taken in the development of the package. The findings of this research will highlight the problems that can befall the development of resources such as the EDEC package when little attention is paid to good practice in the selection and use of media and where a cursory approach is taken to evaluation (Reeves, 1999).

1.3. Issues Raised on the Usability of EDEC

The initial evaluation of the EDEC package was intended to establish its effectiveness as a resource in relation to accepted definitions of usability. Fitzpatrick and Higgins (1998) collated a number of definitions which highlight factors that are important to the design of effective human-computer interfaces (Table 1).

Source	Definition
McCall et al.	The effort required to learn, operate, prepare input and interpret output of a program.
Ravden and Johnson	The extent to which an end-user is able to carry out required tasks successfully, and without difficulty using the computer application system.
ISO/IEC 9126, 1991	A set of attributes of software which bear on the effort needed for use and on the individual assessment of such use by a stated or implied set of users.
ISO/DIS 9241-11, 1995	The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

Table 1

While interface design and in particular the use of text, colour and different media has been widely researched (Frenckner, 1990; Muter et al. 1982; Muter, 1996; Nielsen and Molich, 1990; Neilsen, 1994; Silverstein, 1987; Rieber, 1994; Rubin, 1988; Schneiderman, 1987) the EDEC package incorporated some rudimentary flaws which were exacerbated by the inconsistent design approaches adopted by individual consortium members. These included different approaches to the design of the navigational interface, inconsistent and injudicious use of animated and interactive elements and inconsistent approaches to the control of interactive elements and the use of colour.

Figure 3 shows two typical screenshots from EDEC modules developed at different institutions. Each screen shows very different approaches to navigation through the package with buttons located in different areas of the screen. The method for interaction also differs between the two screens with one asking the learner to interact via red text areas, while the other directs the learner towards designated areas within the screen. Confusingly, the Instrumentation Amplifier Circuits screen includes red text as a means of highlighting important information. This text is however not interactive as is the case in the Binary Numbers screen. Even the title of the binary numbers screen, *'Adding Binary Numbers'* used red text although it was not intended to be interactive.

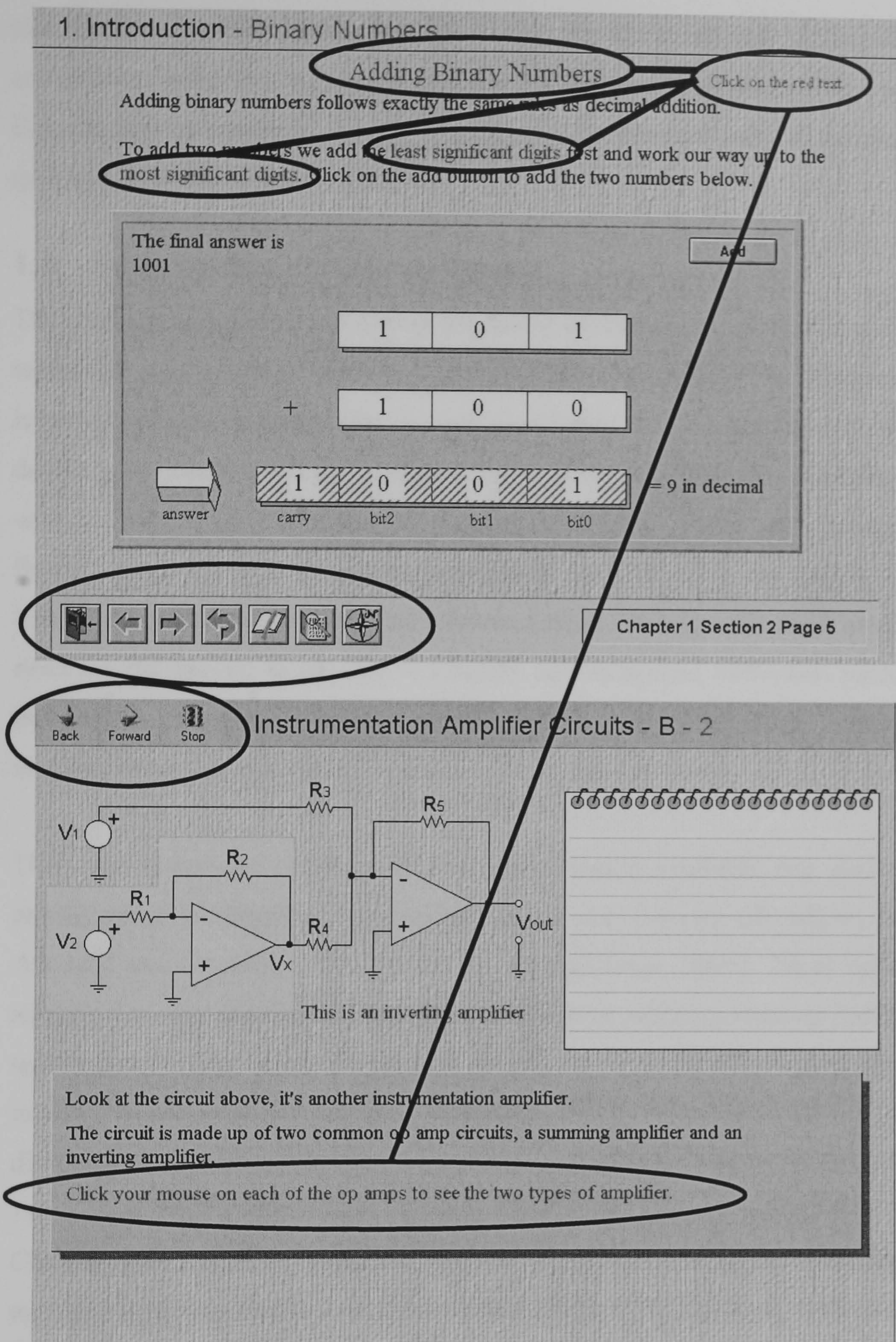


Figure 3

Similarly, the use of blue text for emphasis in segments of the on-screen text also led to the potential for confusion due to convention of using the colour blue to signify Internet hyperlinks. This phenomenon is similar to that observed by Bailey (1982) during the observation of operators in nuclear power plants where confusion was created by the counter-intuitive use of green and red for stop and start buttons in some plants. The lack of a consistent approach to the use of colour for text led to a number of problems with the identification of interactive links during the students' use of the package. These issues will be discussed in more detail in subsequent chapters.

1.4. Information Processing Issues

The shortcomings identified during the initial evaluation of the EDEC package raised the question as to whether it operated in a manner which undermined the learning process. In particular, it was anticipated that certain aspects of the design may impact upon the learner's ability to process information effectively, with concomitant implications for memory and recall. There are a number of factors associated with the use of multimedia that can define the quality of the learner's experience. For example Johnson-Laird (1993, p. 132) highlighted the need for the learner to be able to classify and categorise individual pieces of information to gain a holistic understanding before effective conceptual understanding can take place.

There are a number information processing models available that depict the physiological relationship between our senses and memory (Broadbent, 1958, Atkinson and Shiffrin, 1968, Mayer, Heiser and Lonn, 2001). These typically identify two components of memory, short-term or working memory and long-term memory. Our ability to process information into working and long-term memory can be related to a number of external factors which have been variously discussed in the literature (Baddeley, 1999; Johnstone, A.H. & El-Banna, H, 1989; Gray, 1997; Miller, 1956; Johnson-Laird, 1993; Schnotz & Kulhavy, 1994; Clark & Paivio, 1991; Chun and Plass, 1997; Paivio, 1986). Four key factors emerged from the distillation of the literature which informed the evaluation of the EDEC package. These were,

- the complexity of information;
- the amount of information that is required to be processed;
- the way in which information is presented;
- the time available for processing.

A detailed analysis of a number of EDEC modules and their contents was carried out prior to the evaluation of the package with students to determine the different characteristics of various screen types. This resulted in the identification of four different screen types as shown in Table 2.

Screen Type	Description of Content
1	Screens where physical interaction between the subject and the screen was not anticipated beyond the reading of text and/or review of static images.
2	Screens where subjects were expected to review a concept through the reading of text and review of animation.
3	Screens where subjects were expected to review a concept and then interact with the package to consolidate their understanding of the concept. These typically included multiple choice or drag and drop type questions.
4	Screens where subjects were expected to carry out a calculation and input an answer directly to the package.

Table 2

It was anticipated that each screen type would require different approaches to the processing of information and impose a different cognitive load on the learner depending on the delivery of information and the screen layout. An example screenshot, where the cognitive loading applied to the student was assumed to be minimal is shown in Figure 4. The text is initiated by the user clicking on the 'Objectives' button which brings the text in as animated bullet points. Each sentence can be processed sequentially as separate chunks of information, similar to the reading of a book. This phenomenon will be discussed in greater detail in chapter two. The time allowed to process the first sentence was however limited to 3 seconds before the second sentence was initiated, leading to the potential for reader distraction as my own tests concluded that around five to six seconds would be required to process each sentence.

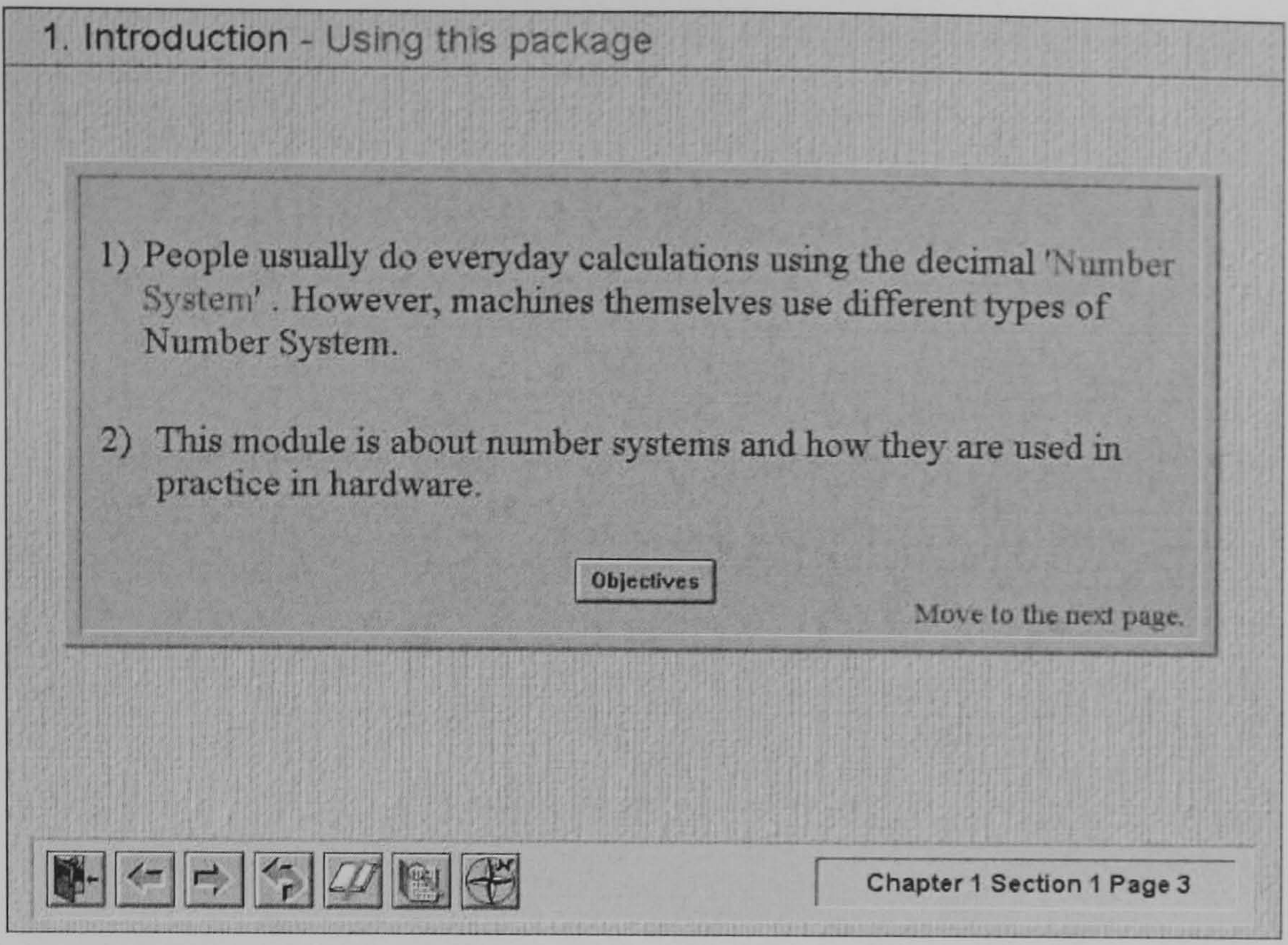


Figure 4

Simple animated elements were designed to conform to standard reading conventions (left to right) as can be seen in Figures 5 and 6, which includes a simple animation at the bottom of the screen. In this case, the user initiates the animated sequence by clicking on the 'equals' button, with the calculation developing as a single continuous animation which lasts 22 seconds. Although the animation is continuous, the breaking up of the binary number into its individual components '101' allows the learner time to process each part of the calculation in turn, as five individual processing 'chunks' each with no more than three items of information.

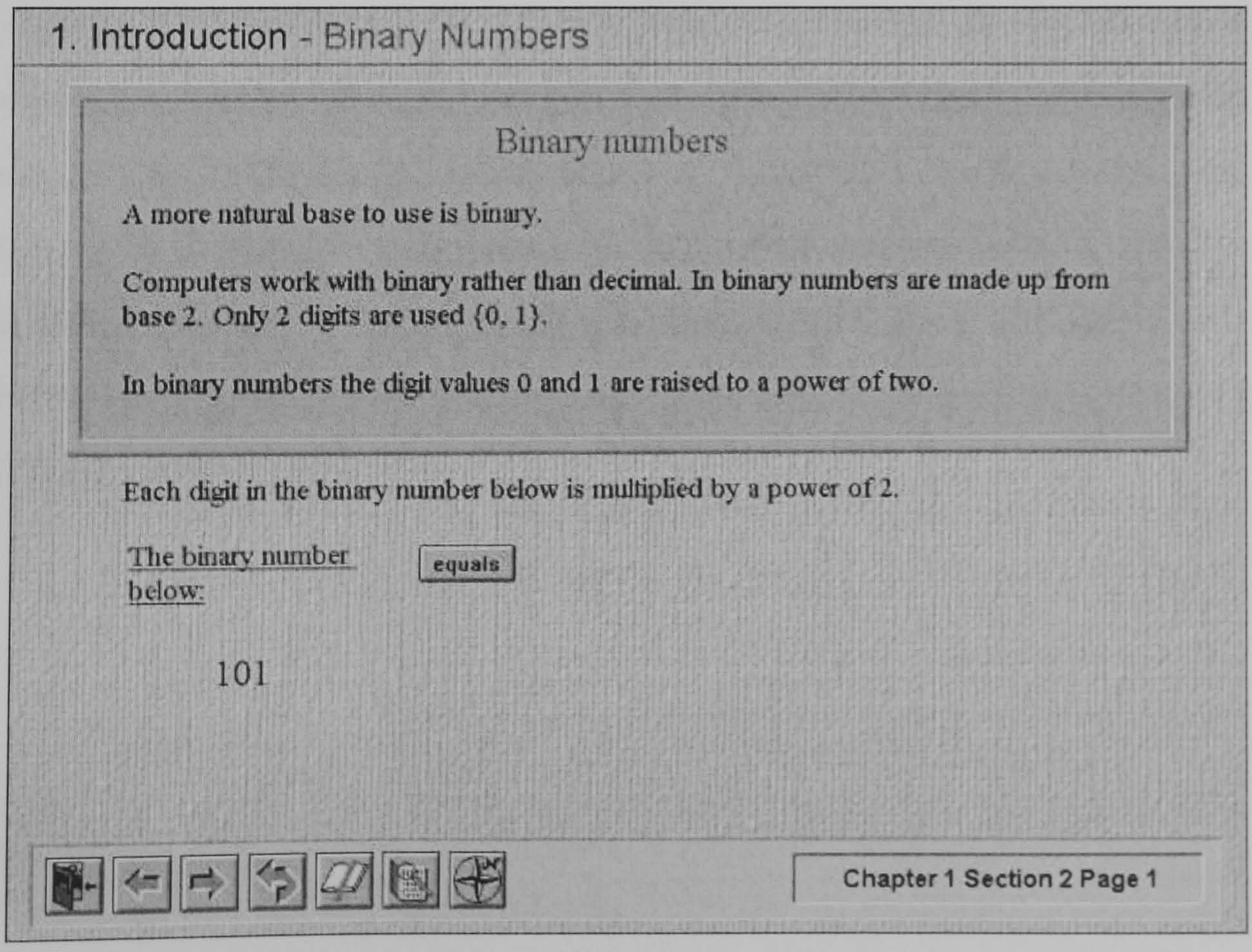


Figure 5

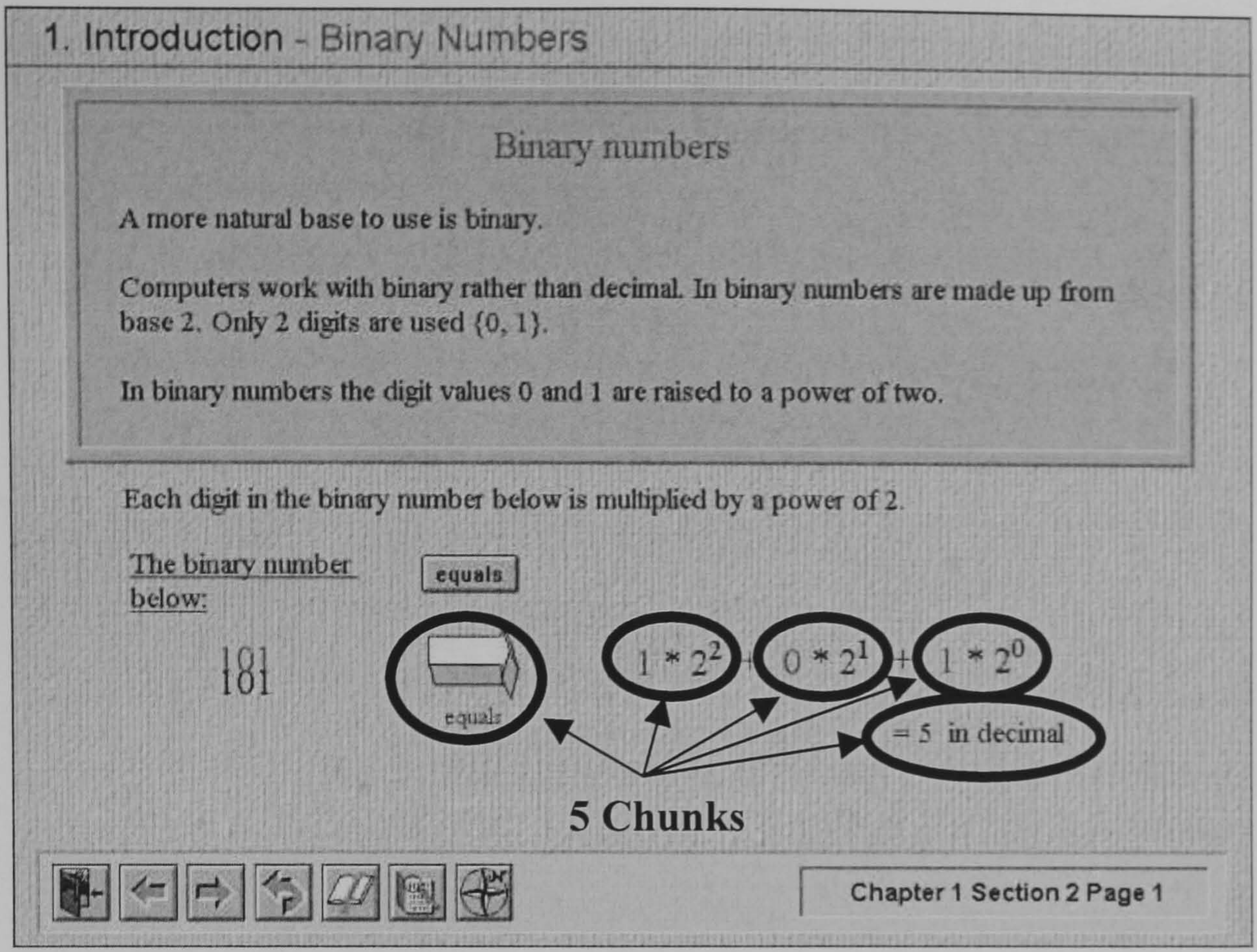


Figure 6

One example of a screen that required a greater degree of information processing, hence placing a greater cognitive loading on the learner is shown in Figures 7 and 8. This animated sequence required the viewer to process 37 seconds of continuously animated information before reaching the end of the sequence. The animation could be broken down into eight individual chunks of information for processing by the learner. Each of these subsequently carried up to four individual items of information. The inability of the learner to control the flow of animated information may also inhibit the learners' ability to process information effectively into working memory as information enters and leaves the screen throughout the animation. This provides the learner with limited time to process each chunk of information in sequence leading to a potential breakdown in cognitive processing as the learner endeavours to process one chunk while another is being delivered. This phenomenon was observed on a number of occasions while observing students' behaviour during the case studies that follow (chapters 4 to 7).

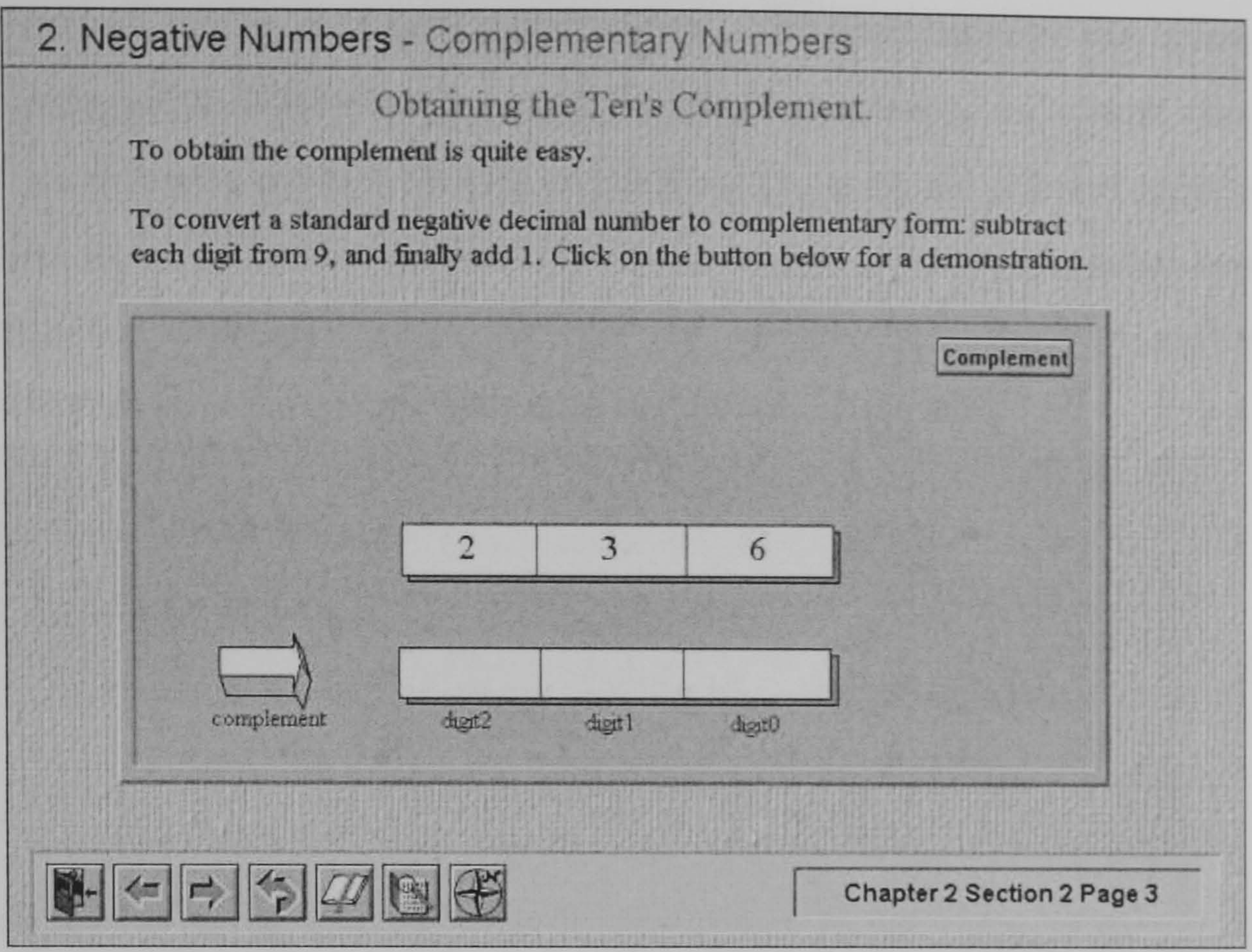


Figure 7

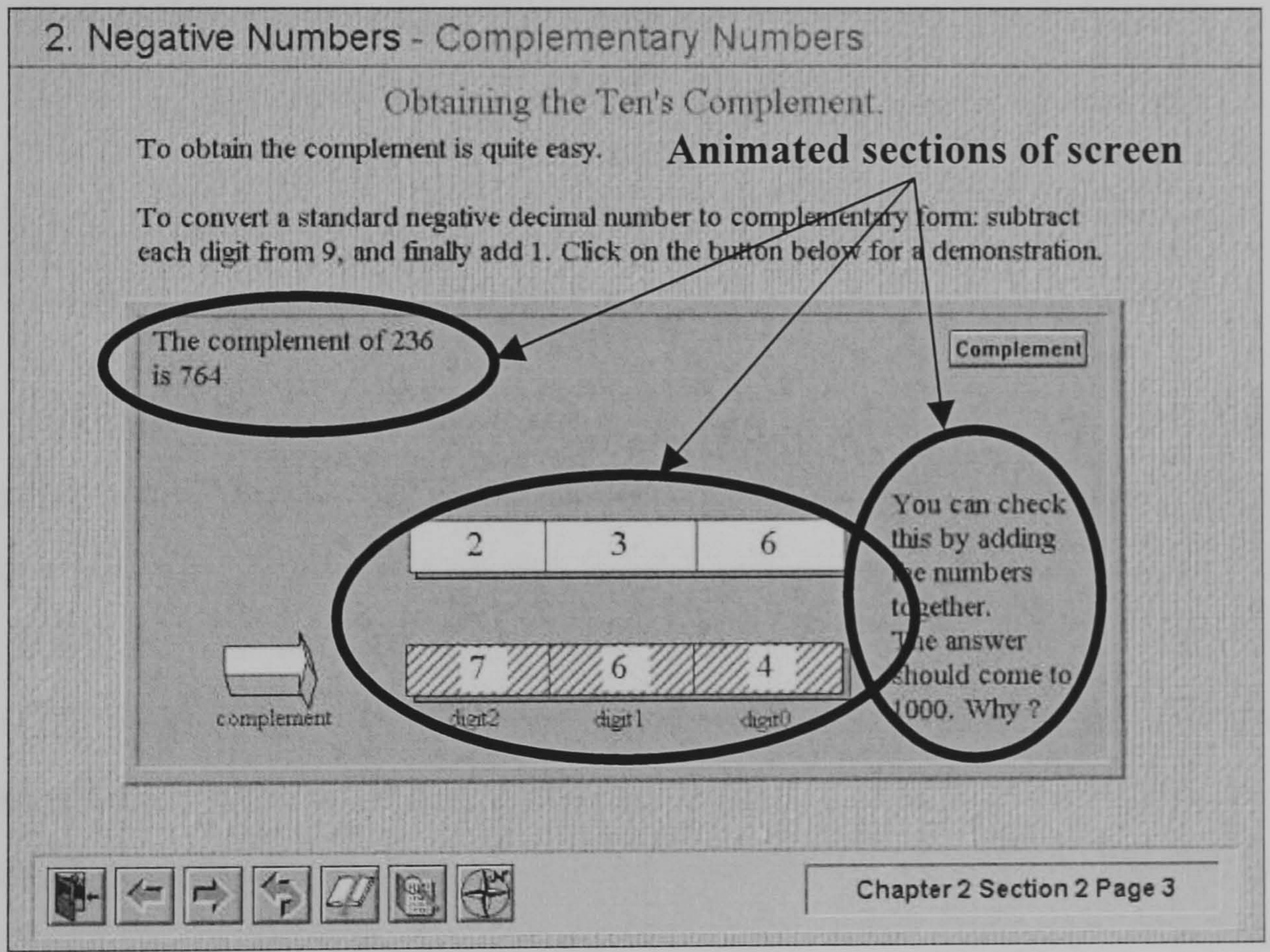


Figure 8

Another area that was considered during the initial evaluation of the EDEC materials was the screen layout and the arrangement of information within the screen as well as the amount of information being presented at any given moment in time. This was of particular interest with regard to students' cognitive style as determined through Riding's (1991) Cognitive Styles Analysis (CSA) test. An example of a screenshot where a large amount of information is being passed onto the learner simultaneously within different parts of the screen is shown in Figure 9. While the 32 second animation is running on- screen, moving images are required to be processed simultaneously from the left and right hand tables and also within the central section of the screen. This results in the learner being required to process textual, pictorial and animated material from a number of different areas of the screen both sequentially and in parallel.

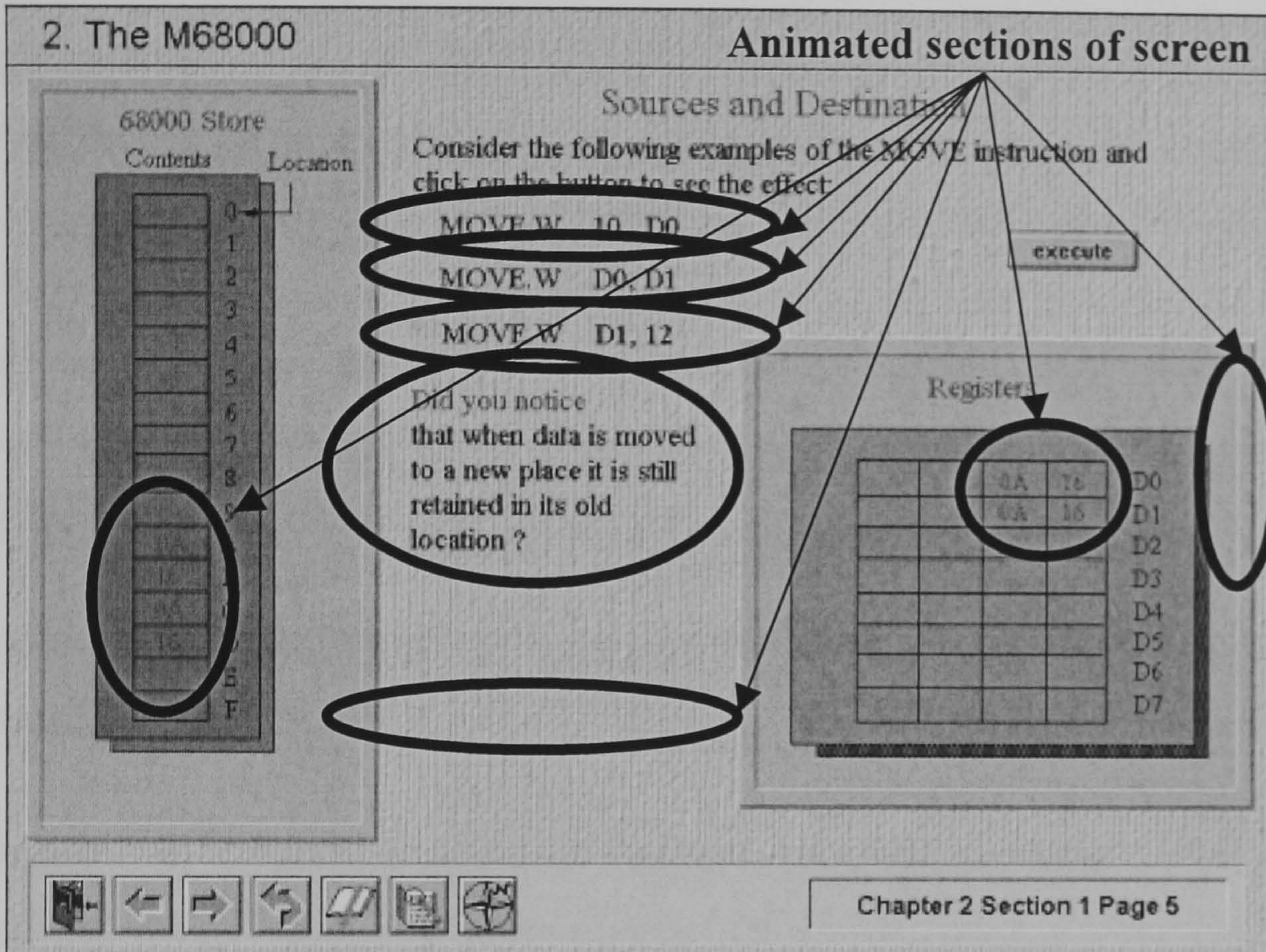


Figure 9

While much of the research into the effects of various media on information processing and learning has been carried out from a psychology perspective (Heiser and Lonn, 2001; Spence and Tsai, 1997, Chou, 2001, Federico, 2000, Hong, 2002, Ghinea & Chen, 2003, Graff, 2003 etc.), an interesting study of the impact of multimedia on the brain challenged some of the psychologists' findings which often implied an additional cognitive burden associated with the processing of multimedia. The study was carried out by Gerlic and Jausovec (1999) and investigated the physiological impact of multimedia on the brain through the use of electroencephalographic (EEG) data gathered from a number of subjects. This enabled them to measure subjects' brain activity during their exposure to text and multimedia presentation. Their findings indicated a reduced cognitive load applied to short-term memory through multimedia presentation when compared with the presentation of information through text.

1.5. Cognitive Styles and Learning Styles

The terms cognitive style and learning style are often used in an interchangeable manner, with numerous definitions of each style construct (Gregorc, 1979; Keefe, 1979; Riding, 1999). Riding and Cheema (1991) for example identified over thirty different labels for the 'style' construct, many of which meant the same thing. This potential for confusion has led to an incoherent view of cognitive/learning styles and the differences between the two. Generally speaking, cognitive style could be regarded as a subset of the learning style construct, although Sadler-Smith (2001) indicated that learning style, in the form of Kolb's model can be seen to be independent of cognitive style and as such, they should be regarded as different constructs altogether. A working definition would be one's organisational and information processing habits in relation to thinking, remembering and problem solving.

Keefe's (1979) definition of learning styles perhaps best describes the wider aspects of this construct:

"characteristic cognitive, affective, and physiological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment."

There is general agreement within the literature that both style constructs are 'stable' in nature which has led to development of a myriad of inventories and other tools for the determination of style (A.L. Benton & O. Spreen 1969, Felder & Silverman, 1988; Witkin et al, 1971 & 1977; Kolb, 1981, Honey and Mumford, 1992; Riding & Cheema, 1991). Others such as Myers-Briggs and Kiersey (1998) have combined elements of the style constructs with factors typically associated with personality and temperament, culminating in a bewildering barrage of psychometric tests available to the researcher.

1.6. Multimedia and the Style Constructs

The ready availability of off-the-shelf tests has led to a rapid growth in research into the effects of multimedia on learning over recent years, with particular attention paid to the role of learning styles and cognitive styles (Spence and Tsai, 1997, Chou, 2001, Federico, 2000, Hong, 2002, Ghinea & Chen, 2003, Graff, 2003 etc.). This for example has led to the development of Web-based learning resources that are intended to take an adaptive approach to the delivery of material according the learner's preferred cognitive or learning style (Ford, 1995, Brusilovsky, 1996, Gilbert and Han, 1999, Papanikolaou et al 2002, Triantafillou et al, 2003, Alomyan, 2004). The concept of developing educational systems which adapt to match the needs of the individual's preferred cognitive or learning style would seem an attractive one although there are those who are sceptical about the effectiveness and desirability of this approach (Landauer, 1995, Eklund, 2000, Draper, 2003). This criticism of adapting delivery to the needs and predispositions of the learner lies in the fact that the outside world does not operate in an adaptive manner. It could therefore be argued that more benefit can be gained by challenging the learner's favoured approaches to learning through means of delivery that are best suited to the learning environment as a whole and not individual learning style.

There are a number of studies that have endeavoured to demonstrate a relationship between learning style or cognitive style and various factors associated with the use of computer and Web-based learning resources (Spence and Tsai, 1997, Chou, 2001, Federico, 2000, Hong, 2002, Ghinea & Chen, 2003, Graff, 2003 etc.). While much of this research recognised the need to take into account the user's predisposition in terms of information processing, their results have been largely inconclusive or limited in demonstrating a relationship between style, perception and performance using computer or Web-based learning resources.

For example, Graff's (2003) study of students' use of Web-based resources and the level of segmentation of these resources did demonstrate a relationship between organisational cognitive style (wholist/analytic) and the level of segmentation or granularity of media using Riding's Cognitive Styles Analysis (CSA) test. Perhaps as one would have hypothesised, analytic learners were shown to be more effective at using resources with a lower level of segmentation than their wholist counterparts due to their greater ability to filter out extraneous information.

Federico's (2000) study of 234 students across a number of disciplines considered their attitudes towards 'network-based instruction'. He employed Kolb's Learning Style Inventory as a means of profiling each student, the results of which were analysed against their responses to an attitudinal questionnaire. His results indicated that 'assimilators' were more likely to respond favourably to this kind of instruction than '*converger*', '*diverger*' and '*accommodator*' students.

Although the aim of developing multimedia resources which are intended to optimise learning through an awareness of cognitive style is a worthwhile one, many studies have demonstrated little or no link between cognitive or information processing style and learning through computer or Web-based media, thus supporting the sceptical position taking by some. Ghinea and Chen's (2003) study which considered the relationship between learners' perceptions of quality of multimedia clips delivered over the Web in relation to their overall learning experience found that cognitive style (field dependence/independence) was independent of quality of perception. They also found that limited network bandwidth had little impact on the user's perception of the quality of the resource overall.

Hong (2002) also found no significant link between learning style and student perceptions, levels of satisfaction and performance using a Web-based resource. He did however highlight the need for teachers and learners to develop strategies for effective use of such a resource within a problem-based learning environment. This again raises the important issues of integration and contextualisation of resources within the learning environment to optimize the potential of the learning experience overall.

Sabry and Baldwin (2003) considered the different forms of interaction that were possible in using Web-based approaches to learning and highlighted three categories of web-based interaction:

- **learner/tutor** – one-to-one, many-to-one or one-to-many synchronous and asynchronous dialogue between learner and teacher.

- **learner/learner** – synchronous and asynchronous dialogue among individual and groups of learners.
- **learner/information** – learner interaction with course specific as well as non course specific learning materials.

They found that the interaction between the learner and information produced the highest response from students in terms of frequency of use and perception of usefulness. Analysis of their results however raised concern as to the potential mismatch between 'perception of use' and 'actual use' of each of the interaction categories. They concluded that there is need for a balanced approach to curriculum development which promotes 'actual use' of each of the three methods of interaction, in order to provide the most beneficial global learning experience for the individual learner.

1.7. A Note of Caution Regarding Psychometric Testing

While a lucrative market in the testing of style and personality has developed in recent years, there is a growing body of scepticism regarding the reliability of many of the instruments which purport to test style and personality (Coffield et al, 2004, Dawes, 1994, Murphy Paul, 2004, Pittenger, 1994). A number of these authors have highlighted the 'self-deception' nature of the questioning in many of the tools used and have called into question the use of such tools in research. Murphy Paul (2004) has gone so far as to suggest that the use of such tests for the profiling of children can actually lead to their *'mis-education'*.

1.8. The Use of Multimedia in Engineering Education

The move towards a more student-centred approach to teaching and learning within an engineering domain can have particular implications for the learner in terms of learning style and learner cognition, as identified in the work of Felder et al (1988, 1995, 1996) and Zywno et al (2000, 2002). Zywno in particular demonstrated the motivational benefits that effective integration of multimedia and hypermedia into engineering courses can offer over traditionally taught courses, although she did not consider the role of the Graphic User Interface (GUI) and its potential to 'date' a resource in her study of 2000. Zywno (2003) also highlighted the dearth of rigorous evaluation of hypermedia based learning interventions within the engineering education domain with regard to pedagogical approaches or student learning.

Felder and Silverman's (2002) contention that the learning styles of most engineering students is incompatible with the teaching style of most academics highlighted the need for an awareness of learning styles among academic staff no matter the discipline. It also highlighted the need for teachers to see the learning environment through the eyes of the learner if teaching style is to be matched with learning style, although they did acknowledge that this can create an additional burden on staff time during delivery. The introduction of compulsory staff development programmes leading to formal qualifications in teaching and learning within many universities has gone some way in providing non-educationalist staff with the support necessary to develop appropriate and innovative teaching strategies that promote effective learning.

1.9. Conclusions

Institutions need to consider the effective use of new technologies if they are to remain competitive in the wider market that higher education has become. In the not too distant future, the Web as an educational tool may take a form which is less altruistically driven than today. The need for effective means of delivering flexible education to large numbers of students is therefore vital, if individual institutions are to retain what could increasingly be seen as 'market share.' Web-based education is one means of providing a platform for mass education, which is not defined by the boundaries that restrict present in-house courses.

The purpose of the research was to consider whether certain students were advantaged or disadvantaged by the form of delivery of the EDEC package and in particular through the use of animated media. The intention was to test the effects of cognitive style and approach to learning on students' use of the EDEC package and evaluate these factors alongside stakeholders' perceptions of the package and their approach to information processing and problem solving. This was achieved during the first three case studies through a quantitative analysis of factors relating to the students use of EDEC. The use of think-aloud during the final case study allowed student processing of information from EDEC and problem solving to be evaluated alongside the method of delivery. The methods chosen and their use during the research will be discussed along with the results of the study in the subsequent chapters.

Based on the initial survey of the literature, it was established that great care must be taken to design learning systems which accommodate the range of cognitive styles and strategies that distinguish individual learners, while providing a rich and diverse learning experience for all.

Chapter Two

Theoretical Underpinnings of the Research and the Development of a Conceptual Framework

2. Introduction

This chapter will discuss the development of a conceptual framework for the research based around the general hypothesis that some students may be disadvantaged by the use of the EDEC package due to cognitive predisposition (cognitive style) and/or approach to learning (deep or surface). It will also consider the underpinning theory associated with these factors as a means of defining and refining the methods and instruments used in the research. Entwistle's heuristic model (1987) of learning provided a useful starting point in this exercise as it considered a number of factors in relation to applicable stakeholders (Figure 10). His model clearly highlights the complex nature of learning and the important role that individuals and groups of people play in determining the learning experience.

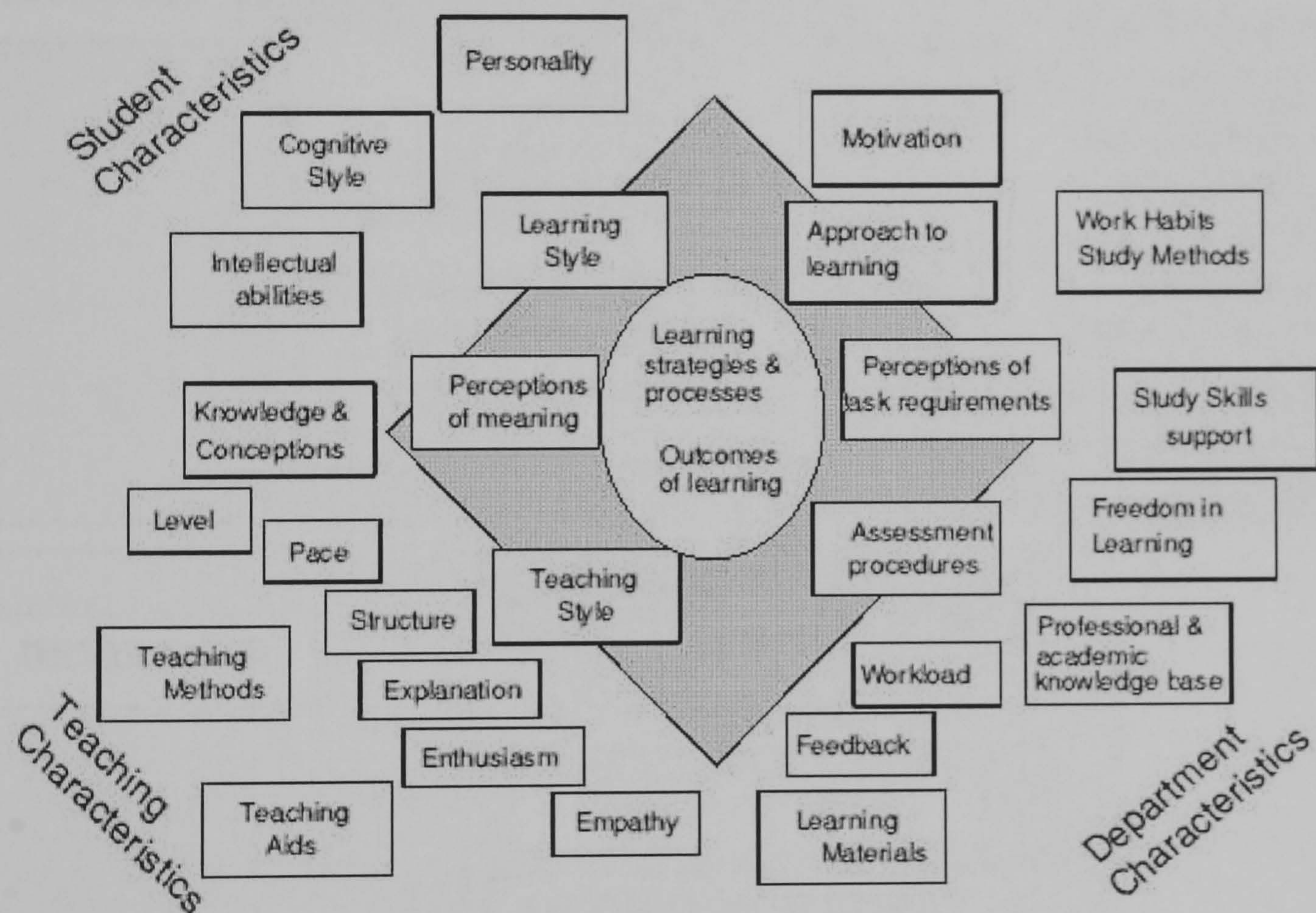


Figure 10

As a means of focusing the review of the literature a conceptual framework was developed with a view to identifying key relationships between stakeholders (teacher, learner and developer) and factors that had a role to play in defining the learning experience with the EDEC package (Figure 11). The choice of media and method of delivery were considered to be central to the experience of the learner in relation to a number of influential factors such as approach to learning and cognitive style.

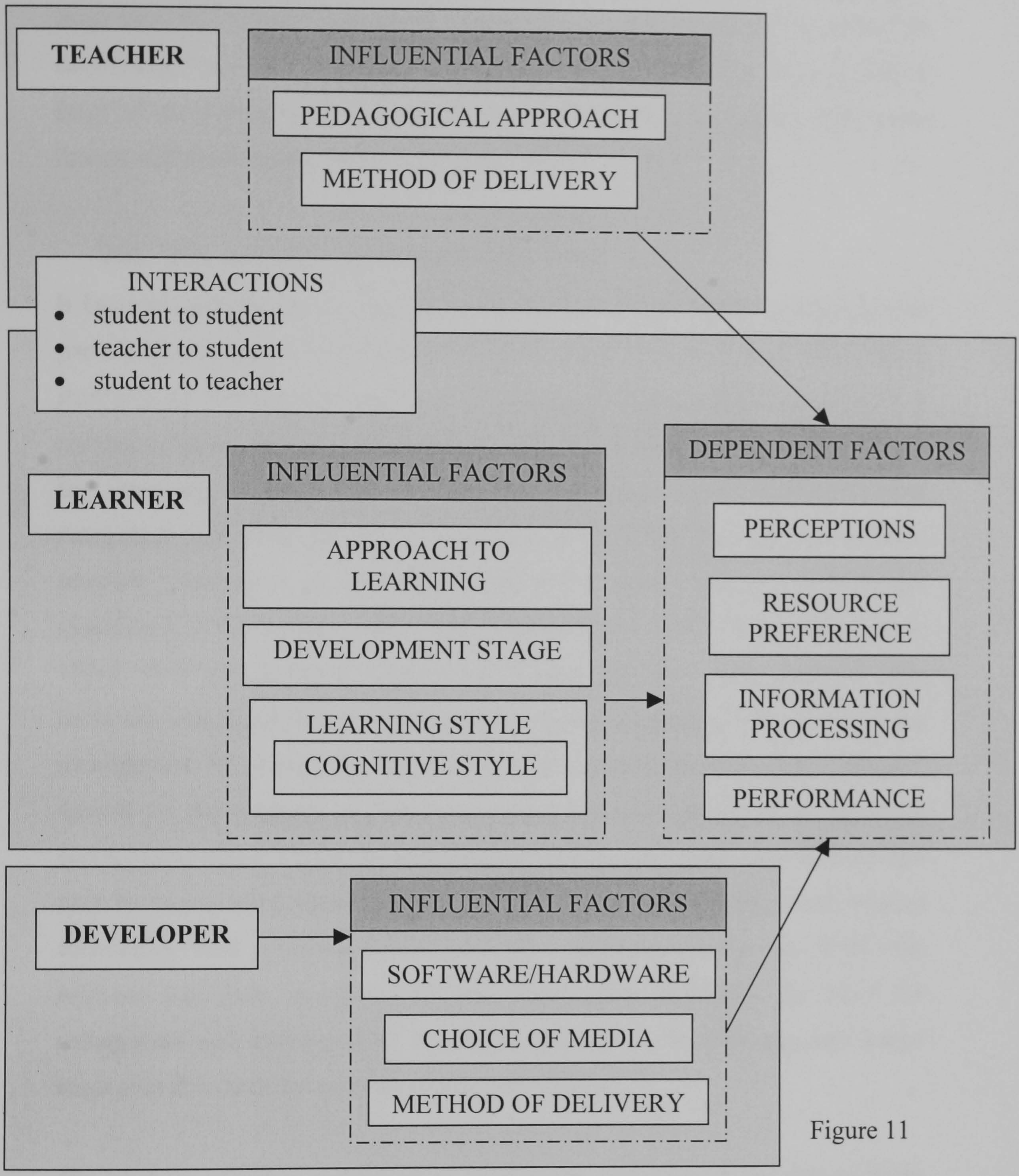


Figure 11

The framework shows the main factors associated with particular stakeholders and their relationship with others. For example the EDEC developer may decide upon the choice of media and method of delivery which will have consequent implications for computer hardware and software requirements. It will also have implications for the teacher in setting the learning environment and for the student in terms of information processing and preference based on a combination of influential factors such as approach to learning and cognitive style. It is therefore fair to conclude that the decisions made at the development stage may be pivotal in defining the quality of the learning experience based on each learner's cognitive predisposition and approach to learning as well as their stage of development (Perry, 1970, 1981). The theory associated with these factors will be discussed in the following sections.

2.1. The Act of Learning and the Web

It became clear during my discussions with staff at each of the institutions that participated in the research that the EDEC package was intended to act as a surrogate for the teacher through the replacement of traditional lectures with a number of EDEC modules. While there are benefits that can be achieved through the replacing of traditional lectures with computer based resources, it is recognised that these should go beyond cost and time savings and requires sensitive integration of resources within the wider learning environment (Laurillard, 1993, Doughty et al, 1995, Draper et al, 1996; Pahl, 2003; Stoner, 1996). Pahl for example stressed the impact that the introduction of such resources may have on cost, pedagogical ethos and learning. His study of the management of change in Web-based learning environments also cautioned against the development of Web-based tools that are over-reliant on specialist technologies based on his own experience. He cited the potential problems that may be encountered when complex features are included in resources without considering their maintenance and cost. This raises the question as to who the resource has been designed for, and once again highlights the need for pedagogical and learning aims to take precedence at the planning and design stage over the showcasing of the developers' talents.

The need for effective integration is particularly important in the case of Web-based resources. While the very open structure of the Web may be said to promote a constructivist approach to learning as described by a number of seminal authors (Dewey, 1916; Piaget, 1952; Vygotsky, 1986; Bruner, 1966). Ford and Chen (2000) acknowledged that the non-sequential structure of the Web necessitates a degree of skill on the part of the learner in the structuring and managing of information for effective learning to take place. When we add to this the dynamic interactions between the teacher and the learner (Pask, 1975; Laurillard, 1993) the complex nature of learning within this type of environment becomes apparent. In this regard, Ausubel's (1968) assertion that educational psychology can be reduced to the single principle of matching teaching to the learner's prior experience and knowledge becomes particularly salient and also alludes to the conduit that allows learning to take place - memory.

2.1.1. Memory - Information Processing and the Impact of Media

The benefits attributed earlier to Web-based resources often centre on the ability to deliver rich and interactive content through multimedia. The ways in which these media are delivered and processed are however important to the retention of knowledge and understanding. This requires a means of storing and retrieving information as and when required. This store is called memory. Baddeley (1999, p.19) stressed the need to be able to differentiate between different forms of memory and the ways in which they operate. He described memory as an array of interacting systems for encoding, registering and storing information for later retrieval as against one unitary system. While the labels associated with the various forms of memory vary, studies have generally agreed on three forms of memory, these being; sensory memory, short-term or working memory and long-term memory. The different categories of memory function as a consequence of our sensory interactions with the environment and sensory stimuli. Atkinson and Shiffrin (1968) developed what was commonly referred to as the 'modal' model for the normal function of memory and its interaction with our environment as described in Figure 12.

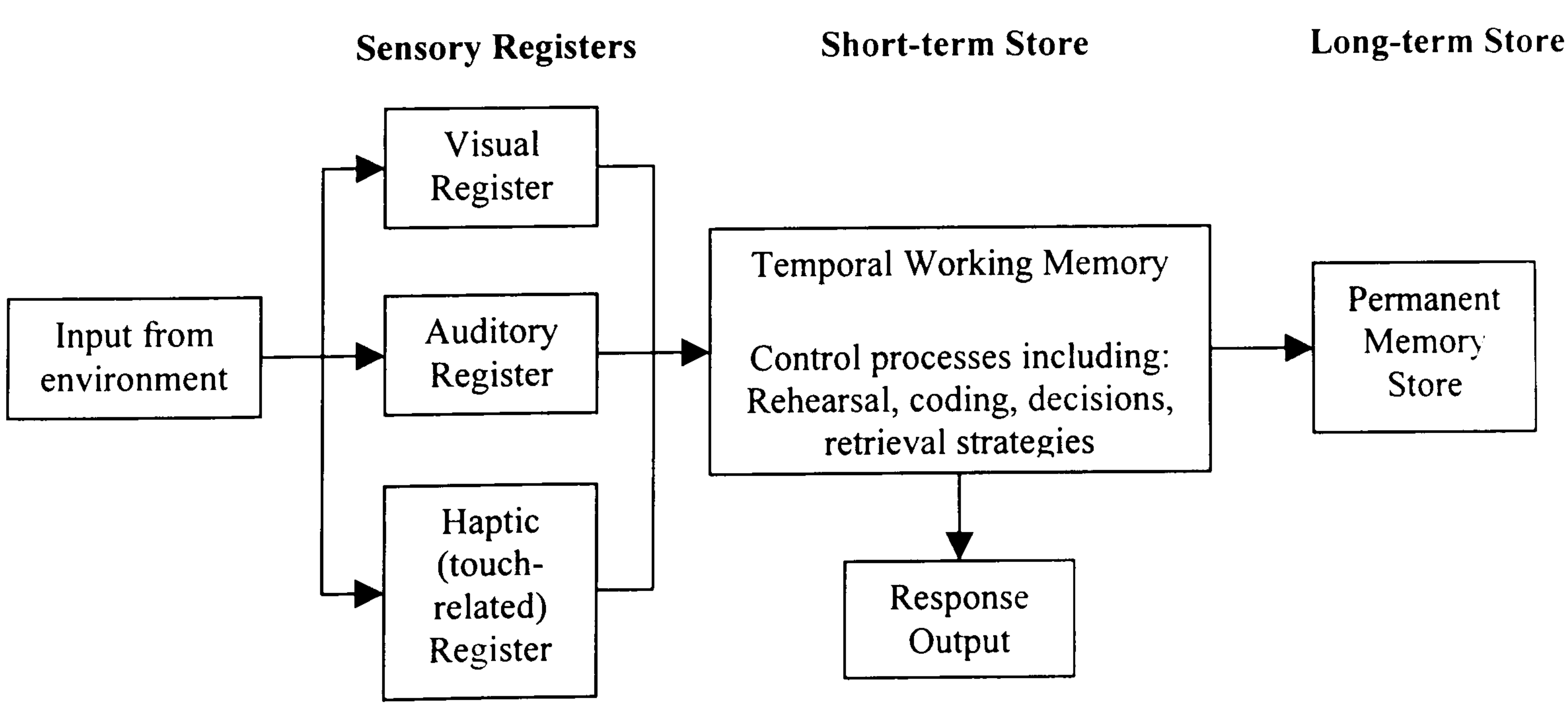


Figure 12

Sensory memory is closely related to perception and the manner in which we process information from the world around us. This form of memory allows us to translate particular sensory stimuli such as light and sound into meaning before storage in short and long-term memory. A number of studies have shown that our senses at any given time are subjected to more information that we are able to process effectively (Broadbent, 1958; Johnstone and El Banna 1989). All information passing through the senses is therefore filtered to allow only the most important information to pass through a channel, thus allowing us to focus on the important information dictated by long-term memory. Johnson-Laird's analogy works well in describing this phenomenon:

> *"If you are at a cocktail party, for example, the selective filter enables you to concentrate on one particular conversation and to ignore all the others in earshot. The filter is controlled by long-term memory, so that if your name is mentioned in another conversation then the filter immediately switches your attention to that conversation."*

Johnstone and El Banna (1989) discussed the importance of recognising the limitations of working memory in the setting of examination questions for example.

> *"A necessary (but not sufficient) condition for a student to be successful in a question is that the demand of the question [Z] should not exceed the working memory capacity of the student [X]. If the capacity is exceeded, the student's performance should fall unless he has some strategy [Y] which enables him to structure the question and bring it within his capacity."*

This finite capacity of working memory was measured in what Miller (1956) described as 'chunks.' The chunks themselves can be any piece of information, e.g. a word, a number, a letter etc. Miller found that although individual learners will vary in their memory capacity, a finite number of chunks (7 ± 2) of information could be held in working memory before overload took place. Gray (1997) gave an example of chunking theory. The sequence of letters *'TDATCM'* could be considered as comprising of six chunks, as could the sequence *'THE*

DOG ATE THE CAT'S MAT'. Clearly, there are more letters contained in the second sequence. However, our working memory will process each word within the sentence as an individual chunk of information since each of the words is recognisable in their own right. Experiments using non-words have shown however that additional processing can be required in the case of non-words such as *'TDATCM'* which would be processed as six separate chunks of information although it is presented in the sequence of a single word. This point is further highlighted by Johnson-Laird who pointed out that it is easier to recognise a letter in the middle of a word than it is in the middle of a non-word. For example, it is easier to identify the letter, K, when it occurs in *'ANKLE'* than if it occurs in the non-word *'XMKTF'*. Theory can explain this phenomenon, whereby the chunk, ANKLE activates the long term memory to the letters which make up the word while in the case of the non-word, no activation process takes place.

Johnson-Laird (1993, p. 132) also highlighted the need for the learner to be able to classify and categorise individual pieces of information (delivered through media) in order to gain a holistic understanding of a particular concept. It could therefore be hypothesised that the response of the learner to different forms of media may impact upon their ability to make sense of conceptual knowledge in a holistic sense. For example, the learner's response to text has been shown to be different to that of images (Chun and Plass, 1997). Text delivers information to us through the symbolic structure of language and is processed in a sequential nature; i.e. word by word, sentence by sentence (Schnotz & Kulhavy, 1994). Images however deliver their information in a very different way, by means of a visuo-spatial structure; i.e. the spatial arrangements of the components of the image. Thus images could be said to employ an analogous property which encodes information in parallel or simultaneously (Paivio, 1986, Clark & Paivio, 1991).

The combination of Broadbent (1958) and Johnstone and El Banna's (1989) work highlights the relationship between media, processing and memory. While Hunt (1982) suggested that the organisation of memory is so efficient that we can process and utilise information from images, sounds, symbols and text without great exertion there is a fair degree of evidence to show otherwise. Problems may arise for example through *'selective filtering'*, where different media are presented simultaneously, resulting in task interference which can lead to information being lost to the student as he or she concentrates on one particular media format (Kirby, 1993; Mayer, Heiser and Lonn, 2001). Kirby's work for example indicated that task interference can occur when the delivery of media is dependent on time, thus limiting the processing time available to the learner. Earlier work by Mayer and Anderson (1991) interestingly indicated that the combination of animation and auditory narrative can in fact increase learner retention because the learner is able to process information simultaneously through two separate sensory channels.

The use of imagery is particularly important in the engineering domain where communication often requires the processing of diagrammatic information; for example, a circuit diagram or vector diagrams to demonstrate mechanical force. In both these examples symbol systems and specialist notation are employed which are specific to the field of study. The use of symbolic images in engineering and the form of delivery may therefore have an impact on the learner's ability to effectively process and make sense of any concept. The nature and make up of a symbol, which is an abstraction of some real world entity, must be correctly decoded and interpreted, if it is to prove useful to the viewer. Winn (1993) for example highlighted the *'preattentive'* nature of perceptual processing, where visual information is initially processed in a 'global' manner. He broke this preattentive phase into two different kinds of processing, 'discrimination' and 'configuration'. His example of a circuit diagram exemplifies this concept.

> *"For example, a circuit diagram might show symbols for capacitors, transistors and resistors. Perceptual discrimination detects similarities and differences among the symbols, determining that some are the same and others are different. Configuration places the capacitors, transistors and resistors into groups on the basis of their physical proximity, their connection to each other by lines (wires), or their inclusion in common boundaries (showing sub-assemblies of components). Thus perceptual structure is determined by the grouping of symbols by their appearance (discrimination) and by their placement and interconnection*

(configuration)."

Winn's observation highlights the complexity of understanding and processing that may be required, before productive meaning can be made of engineering language, which often contains domain-specific terminology and specialist symbol systems. This issue will be discussed in greater detail during chapter 6 (case study 4) where there was evidence of some students experiencing difficulty with the processing of binary and hexadecimal notation due to their inappropriate mapping of these number systems to decimal notation.

2.2. The Development of Individual Learner Profiles

Two of the key influential factors identified within the conceptual framework were cognitive style and approach to learning. The important difference between these factors being that one is typically regarded as being stable (cognitive style), while the other (approach) can change according to the influence of other factors. The general hypothesis that the learning experience provided by EDEC may be affected by one's cognitive style and/or approach to learning led me to consider methods and instruments that would allow the development of a learning profile for each student who participated in the research. These would form the basis for a wider investigation of their individual and group behaviour during their use of the EDEC package in relation to a number of other factors such as performance and perception. The following sections will discuss some of the theory relating to both learning style, cognitive style and the factors that may influence one's approach to learning as a precursor to the selection of instruments for the testing of cognitive style and approach to learning.

2.3. Learning and Cognitive Style Constructs

The stable nature of both learning and cognitive style constructs stimulated an interest as they would appear to influence the learner without the ability to change one's style. This relates closely to personality, which Eysenck and Eysenck (1985) defined as, *'...a more or less stable and enduring organisation of a person's character, temperament, intellect and physique, which determines his unique adjustment to the environment'*. Some authors (Furnham, 1992, Jackson & Lawty-Jones, 1996) have gone so far as to suggest that models of learning styles such as those developed by Kolb (1981) and Honey and Mumford (1992) could be regarded as subsets of personality and need not be measured independently.

Personality was at the heart of Kolb and Fry's (1975) work on experiental learning which culminated in the development of their *'Learning Styles Inventory'* (Kolb, 1976, 1981). They defined four learning styles, accommodator, diverger, assimilator and converger. Each style was determined by the learner's approach to tasks as described by the four dimensions below.

1. **Concrete experience** - learning which is derived from specific experience, relating to people and sensitivity to feelings and people.
2. **Reflective Observation** – careful observation before making judgement, viewing things from different perspectives and looking for the meaning of things.
3. **Abstract conceptualisation** – logical analysis of ideas, systematic planning, acting on intellectual understanding of a situation.
4. **Active experimentation** – ability to get things done, risk taking, influence people and events through action.

By combining dimensions across the four quadrants learner types were identified as shown in Figure 13. For example, *'divergers'* would typically be expected to prefer *'concrete experience'* or *'reflective observation'* tasks.

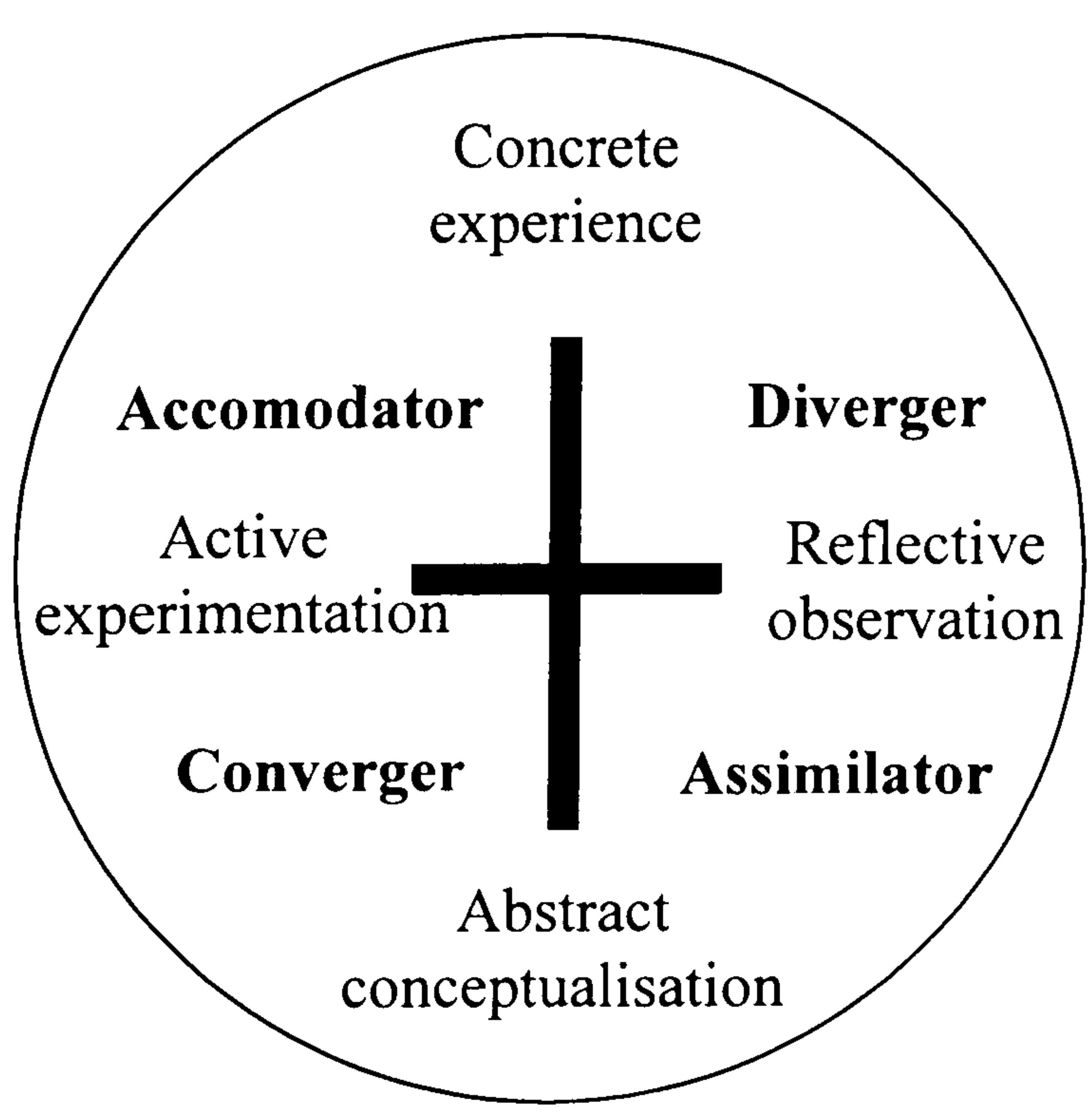


Figure 13

Dunn and Dunn (1978) took a different approach to learning styles by combining external and internal characteristics of learning. They developed four categories relating to personality and external physical stimuli which were subdivided into specific elements for each category of stimulus. Their original four factors were environment, emotional, sociological and physical, although in later work (Dunn and Dunn, 1989) they added a fifth category relating to cognitive style (*'psychological cerebral preference'*). Their intention was to demonstrate a relationship between the various stimuli and different elements that are connected to them (Table 3).

Stimuli	**Elements**					
Environmental	Sound	Light	Temperature	Furniture design		
Emotional	Motivation	Persistence	Responsibility	Structure		
Sociological	Colleagues	Self	Pair	Team Small Group	Authority: teacher directed	Varied
Physical	Perceptual	Intake: food	Time	Mobility		
Psychological Cerebral Preference	Analytic	Global	Reflective	Impulsive		

Table 3

In the engineering domain, Felder and Silverman's (1988) model of learning styles, was later developed into a 44 question instrument, the *'Index of Learning Styles'* (Felder and Soloman, 1991), which encompassed elements of sensory cognitive style and learning style over four dimensions, these being, *'active/reflective'*, *'sensing/intuitive'*, *'visual/verbal'* and *'sequential/global'*. This model has the benefit of delivering a learner profile that encompasses elements of cognitive predisposition as well as personality type. Its development also highlighted the evolutionary nature of research into learning styles. This is evidenced in Felder's (2002) redevelopment of the original model, where he dropped the inductive/deductive dimension and amended the original visual/auditory dimension to visual/verbal. The reasoning behind Felder's removal of the inductive/deductive dimension is interesting in that it was largely politically inspired. He worried that evidence of deductive preference among learners may result in the design of teaching that matches this aspiration, resulting in a swing away from problem and enquiry based approaches to learning. The change from auditory to verbal was more logically inspired as the term 'verbal' was determined to be a more versatile descriptor for written prose. This model was of particular interest as it has been widely validated with Engineering undergraduates (Felder and Spurlin, 2005), although the actual selection of a suitable instrument predated this study.

Riding and Cheema's (1991) work focused more on cognitive style which they categorised in two dimensions which formed the basis of the Cognitive Styles Analysis test (CSA). These were:

1. The *Wholist-Analytic Style* dimension of whether an individual tends to *organise* information into wholes or parts.
2. The *Verbal-Imagery Style* dimension of whether an individual is inclined to *represent* information during thinking verbally or in mental pictures.

Much of the basis for their wholist-analytic style dimension was derived from Benton and Spreen (1969) and Witkin's (1964, 1971) work on field dependence which considered the influence of the arrangement of information on the learner's ability to effectively and efficiently organise and process it. This he described as field dependency. Palmer (2002) later provided a good working definition of field dependency.

> *"The more able an individual is at breaking up an organised field so as to separate relevant material from its context, or discern signal (the relevant) from noise (the incidental and peripheral), the more field independent that individual is."*

In order to be able to test for field dependency, Benton and Spreen developed the 'Embedded Figures test', which used shape recognition as a basis for determining field dependence. The test was further developed by Witkin et al (1971, 1977) with the Group Embedded figures test. Riding's Cognitive Styles Analysis test (CSA) differs from both embedded figures and group embedded figures tests in that it takes a bi-directional approach to the testing of field-dependence/independence (i.e. testing for both) as against the uni-directional approach of the embedded and group embedded figures tests which in actual fact test for field dependence.

2.4. Studies of Style and Computer and Web-based Learning

Graff's (2003) study of students' use of Web-based resources and the level of segmentation of these resources demonstrated a relationship between organisational cognitive style (wholist/analytic) and the level of segmentation or granularity of media using Riding's Cognitive Styles Analysis (CSA) test. Perhaps, as one could have hypothesised, analytic learners were shown to be more effective at using resources with a lower level of segmentation than their wholist counterparts due to their greater ability to filter out extraneous information. Federico's (2000) study of 234 students across a number of disciplines considered their attitudes towards 'network-based instruction'. He employed Kolb's Learning Style Inventory as a means of profiling each student, the results of which were analysed against their responses to an attitudinal questionnaire. His results indicated that 'assimilators' were more likely to respond favourably to this kind of instruction than 'converger', 'diverger' and 'accommodator' students.

While an awareness of cognitive style may be useful to the multimedia developer, a number of studies have demonstrated little or no link between cognitive or information processing style and a range of learning factors using computer or Web-based media. For example, Ghinea and Chen (2003) whose study considered the relationship between students' perceptions of multimedia clips delivered over the Web in relation to their overall learning experience found that cognitive style (field dependence/independence) was independent of quality of perception. The lack of any clear and consistent relationship would perhaps incline towards the sceptical position taken by a growing number of academics with regard to the significance of cognitive style as an influential factor in learning (Coffield et al, 2004, Dawes, 1994, Murphy Paul, 2004, Pittenger, 1994).

2.5. The Determination of Cognitive Style

With both sides of the debate regarding the influence of cognitive style in mind I took the decision to nevertheless explore the relationship between style and the dependent factors outlined within the conceptual framework. After considering a number of tests for both learning style and cognitive style Riding's Cognitive Styles Analysis (CSA) test was selected as the two style dimensions assessed (organisational and sensory) could be related to their information processing behaviour during their use of EDEC as well as their perceptions of the package. The CSA test was developed in a manner that purported to avoid confusion with other factors such as personality and intelligence, with correlations between the test and other tests for intelligence and personality being generally very low (Riding and Pearson, 1994; Riding and Agrell, 1997, Riding and Wigley, 1997).

The test itself has three sections. The first entails a word association test which is intended to test the respondent's visual or verbal processing of information. The second section tests the learner's spatial awareness through the identification of shapes that are oriented in different ways and the final section asks learners to identify shapes within more complex shapes in order to test for field dependence/independence. Administration of the test is carried out via any Windows™ based PC and takes approximately 15 – 20 minutes to complete. Data is logged automatically for each individual user upon completion of the test and each respondent is subsequently categorised according to their ratio scores as indicated in Table 4.

THE DIMENSIONS OF COGNITIVE STYLE

WHOLIST-ANALYTIC DIMENSION			
>1.35	ANALYTIC VERBALISER	ANALYTIC BIMODAL	ANALYTIC IMAGER
>1.02 and <=1.35	INTERMEDIATE VERBALISER	INTERMEDIATE BIMODAL	INTERMEDIATE IMAGER
<=1.02	WHOLIST VERBALISER	WHOLIST BIMODAL	WHOLIST IMAGER
	<=0.98	>0.98 and <=1.09	>1.09

VERBAL-IMAGERY DIMENSION

Table 4

2.6. Deep and Surface Approaches to Learning

Riding and Sadler-Smith (1997) distinguished between style as learner predisposition and approach to learning which can change according to a number of other factors, including teaching method, learning environment and motivation to complete a given task. The learning experience may therefore vary from one student to the next based on a combination of factors including strategy and motivation. The constructivist paradigm of learning based on the conceptualisation and connection of individual items of knowledge to one's own prior knowledge may indeed promote learning, but the quality of the experience may be determined by the motivation of the learner in the first place and the strategies employed in building knowledge. This combination of motivational and strategic factors is often referred to in terms of *'deep'* or *'surface'* approaches to learning. Ramsden (1988) summarised the characteristics of deep and surface learners (Table 5).

Deep Learner	Surface Learner
Focus is on 'what is signified	Focus is on the 'signs' (or on the learning as a 'signifier' of something else)
Relates previous knowledge to new knowledge	Focus on unrelated parts of the task
Relates knowledge from different courses	Information for assessment is merely memorised
Relates theoretical ideas to everyday experience	Facts and concepts are associated unreflectively
Relates and distinguishes evidence and argument	Principles are not distinguished from examples
Organises and structures content into coherent whole	Task is treated as an external imposition
Emphasis is internal, from within the student	Emphasis is external, from demands of assessment

Table 5

While the aim of educators would generally be the promotion of a deep learning experience, the traditional examination systems employed in higher education could be said to work in opposition to this aspiration, since students' approach to learning is often driven by the extrinsic motivation engendered by summative, end of year examinations. Atherton (1999) highlighted the problems associated with assessment methods that *'reach back'* into courses in a manner which does little more than provide a surface learning experience. He went as far as to claim that there is no evidence of any particular assessment method promoting deep learning without due consideration for the effective integration of assessment within the wider learning environment.

Other research carried out into deep and surface approaches to learning which investigated students' reading and interpretation of academic articles (Fransson, 1977, Entwistle and Robinson, 1976 and Entwistle et al. 1979) indicated a need to further subdivide the two main categories in order to differentiate between students who took an active approach to their learning and those who took a passive approach. Entwistle (1988) summarised these categories as shown in Table 6.

Approach to Learning	**Level of Understanding**
Deep active	Understands author's meaning and shows how argument is supported by evidence.
Deep passive	Mentions the main argument, but does not relate evidence to conclusion.
Surface active	Describes the main points made without integrating them into an argument.
Surface passive	Mentions a few isolated points or examples.

Table 6

Entwistle also highlighted the need for educators to gain an understanding of the relationship between approach to learning and the level of understanding of the student, if a deep approach is to be promoted. This can only be achieved through effective course evaluation and reflection on the part of the educator. He also importantly noted that a deep approach to learning can often go beyond the intellectual capability of the learner. His later research went on to consider a third 'strategic' component of student's learning and understanding. This considered the student's disposition towards the content of a particular course of learning and whether the learning is defined by an 'intrinsic' interest in the content or 'extrinsic' whereby the student is driven by the need to achieve a particular goal or qualification and could therefore be said to be 'apathetic' to the actual course content. Figure 14 shows the relationship between deep and surface strategies and the strategic approach of the learner.

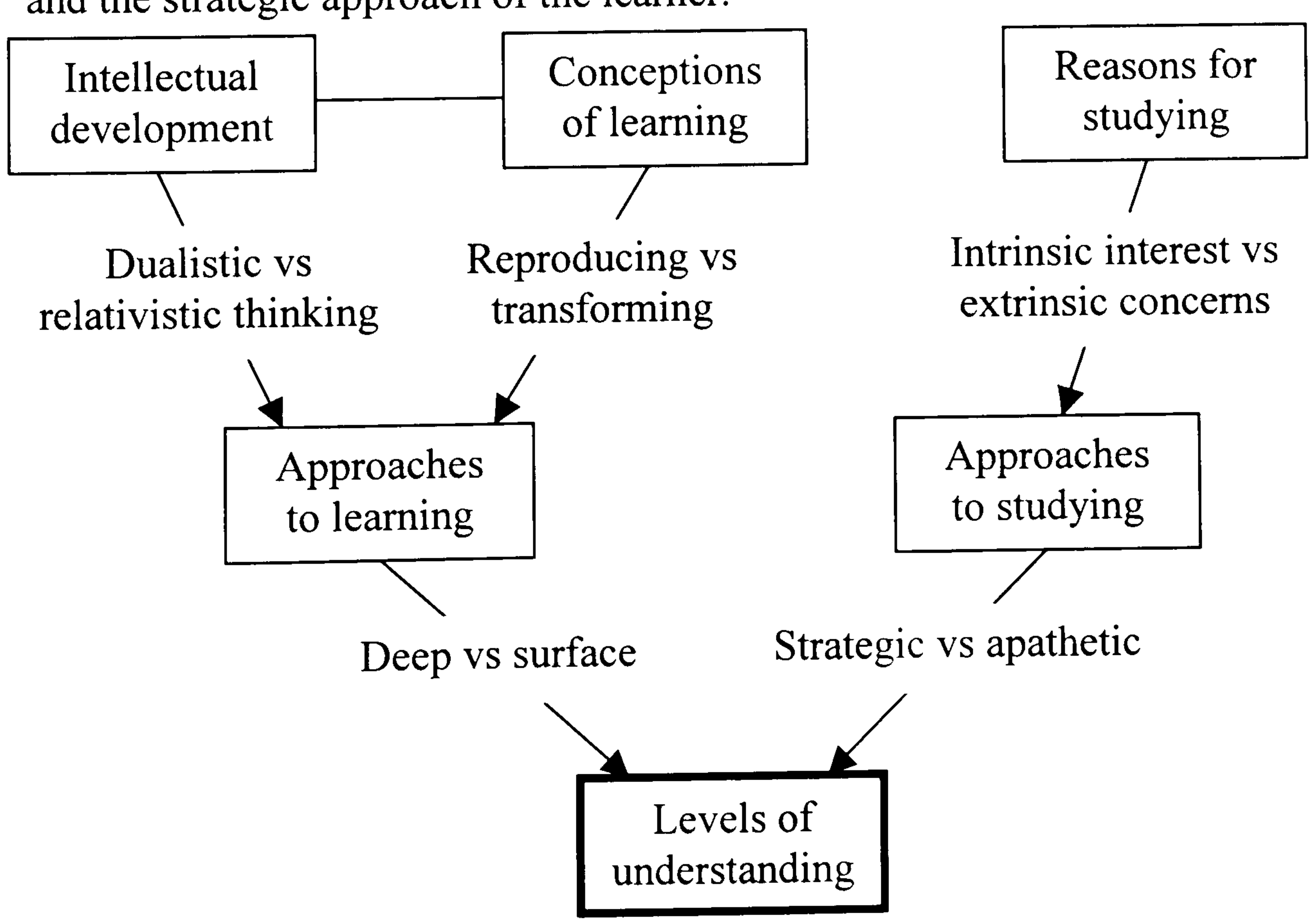
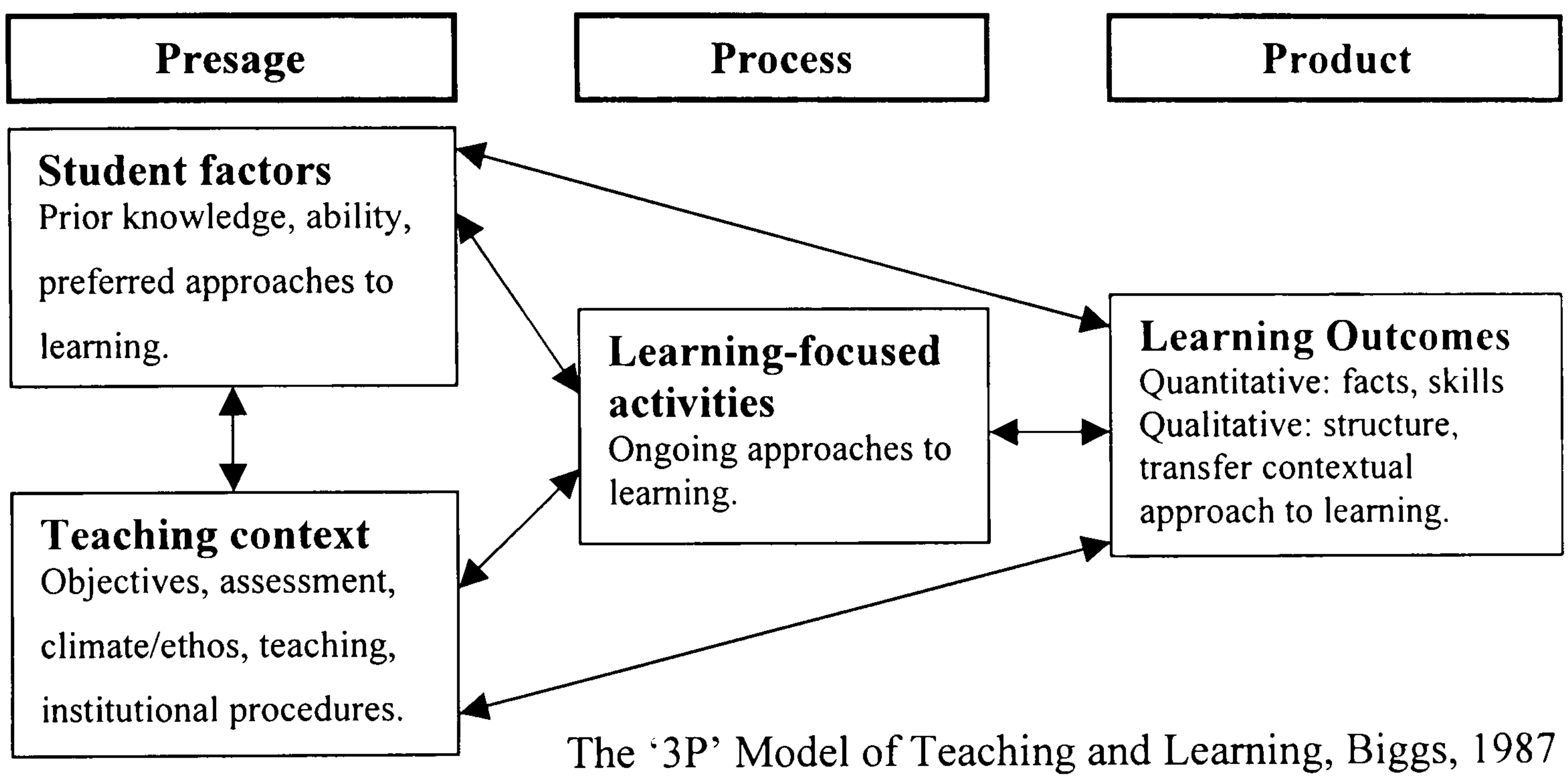


Figure 14

Biggs' research led to his development of the Presage-Process-Product (3P) model (Figure 15), which shows the dynamic system of interactions that combine to allow teaching and learning to take place. Each interaction has a role in determining the ongoing approach to a particular task through to its outcome. It should be noted that the double-ended arrows indicate the reversible direction of each interaction in order to highlight the fact that interactions may change according to context. As an example, Biggs, Kember and Leung (2001) cited instances of the learner's preferred approach to a particular learning intervention adjusting according to how it was being taught.



The '3P' Model of Teaching and Learning, Biggs, 1987

Figure 15

2.7. The Role of Motivation and Self-Theories in Influencing Approach to Learning

One of the key determinants of how the learner approaches a given task is motivation. Motivation in turn is determined by a number of physiological and psychological factors highlighted in Maslow's (1943) seminal 'Hierarchy of Needs'. Although Maslow's model is widely regarded as providing a sound overview of human motivation and its constituent elements, it could be regarded as being rather simplistic as it fails to differentiate between different forms of motivation as identified in later research. Weiner (1984) for example linked examination performance and peer comparison to the establishing of self-worth and personal esteem.

For many learners, motivation towards a particular task can be linked to specific outcomes or rewards (e.g. the need to pass an exam in order to get a good job). Pedagogical approaches can sometimes mirror the behaviourist paradigm by offering rewards for the completion of tasks, although this does not intrinsically guarantee high levels of motivation. Weiner (1990) later went on to highlight the disparity between behavioural theory which encourages an extrinsic approach to motivation through the use of rewards and cognitive theory which strives for an intrinsic approach through the achievement of personal goals. He went so far as to suggest that the rewarding of intrinsic behaviour could act in a counterproductive manner with some learners.

Generally speaking, much of the work on motivation tends to support a constructivist approach to learning which is more likely to encourage intrinsic motivation through contextualisation of learning in relation to the learners` wider world and past experience. Tasks that offer stimulation beyond examinable goals are therefore more likely to engender intrinsic approaches and encourage self-motivated learning beyond the scope of the particular intervention. This is not to say that some tasks may not elicit a surface approach, where purely factual understanding is required as can be the case in medicine and law degree courses or in the study of applied mathematics.

One example which demonstrates the relevance of motivation to students' use of computers relates to the proliferation of computer use as leisure activity through games which has led to highly evolved perceptions of the computer as an entertainment tool. Learning materials and the learners' motivation to use resources such as those developed by EDEC may therefore be judged against the user's wider experience. This could have the effect of demanding more from the developer in terms of the aesthetic value of the graphic user interface as well as the educational content since users have wide experience of slick commercial software. This will be discussed in more detail in subsequent chapters. Malone (1981) developed a theoretical framework for intrinsic motivation which was based around the context of computer use for recreational purposes through games. His theory considered the development of educational software using the characteristics of computer games. He identified three qualities of computer games that promoted intrinsic motivation as shown in Table 7.

Challenge	Activities which involve uncertainty of outcome due to variable levels, hidden information, randomness etc.
Fantasy	The need for specific skills in order to complete the task.
Curiosity	Aroused when the learner believes their knowledge structures to be incomplete, inconsistent or unparsimonious.

Table 7

Malone's work is interesting as it indicated that intrinsic motivation could be achieved within a computer-based learning environment if the resource offered the learner a broad range of challenge, concrete feedback and clear-cut criteria for performance. Although he highlighted generic characteristics of computer games which could be applied to the development of learning resources, he fails to adequately consider the complex role that genre can play in determining motivation among gamers. While some gamers are motivated by the kind of logical problem solving required by adventure or strategy games, others are motivated by the more visceral sensory tasks promoted by driving games for example.

Dweck's (2000) work on self-theories highlighted the important role that one's own perceptions of self can have on our approach to learning. Her extensive research indicated that the learner's goals can be profoundly affected by the fear of failure leading to a lack of risk-taking which can undermine actual learning. She separated these goals into two categories, performance and learning goals. A number of studies (Dweck, 2000, p.16) have shown that when students are asked to select between performance goals and learning goals, around half will choose performance goals, implying a strategic approach to learning which is largely determined by the student's own 'comfort zone'. Dweck defined students who tended to have performance goals as being those who typically wish to be able to succeed without 'looking dumb' and those with learning goals as being students who wish to learn for learning sake irrespective of the potential for failure.

2.8. The Assessment of Students' Approach to Learning

As evidenced in previous sections of this chapter, the learner's approach to learning may be influenced by any number of factors including one's emotional state, strategic goals, personality, motivation, self-esteem and the physical environment. Since these factors are not typically stable, the individual's approach may change with time. The literature generally defines two main characteristics of approach to learning, these being deep and surface. While the factors affecting approach can change with time the learner's general traits can be established and categorised as deep or surface through the use of various inventories.

After considering a number of tests for approach to learning I selected Biggs, Kember and Leung's (2001) Revised Study Process Questionnaire (R-SPQ-2F) as the best instrument due to its assessment of strategy and motivation as subscales of deep or surface approach. Its compact design (20 questions) when compared with other much larger inventories also made it attractive as it allowed me to incorporate it within a composite questionnaire that also evaluated the learner's perceptions and resource preferences.

2.9. The Rationale for my Methodological Approach to Data Gathering

Wolcott (1990) mischievously pointed out that most researchers, in designing and carrying out any research programme, will '*...go to considerable pains not to get it all wrong.*' In order to facilitate the gathering of data across a number of variables, a mixed-methods approach to the evaluation was designed. The rationale behind this approach was to promote the complementary use of methodologies and instruments. While there are any number of methods and approaches that can be used in the evaluation of learning, mixed-methods can provide sound benefits in terms of triangulation of data, typically achieved through the combination of qualitative and quantitative measures. Lawrenz and Huffman's (2002) 'archipelago' metaphor for mixed-methods proposed that mixed-methods should be viewed as a series of islands that are joined beneath the surface of the water. They contended that it is only when we consider the datasets gathered from individual instruments in conjunction with aims of the evaluation as a whole that we can identify and attempt to understand the relationships between instruments and the underlying findings of the research.

The use of mixed-methods can however lead to the potential for conflict between qualitative and quantitative data (Joyes, 1999), although with sensitive approaches to experimental design and appropriate triangulation, problems with data can be reduced. Those who are of a positivist disposition often attribute disparity of results to the subjectivity of qualitative data, although I would argue that conflicting findings should be regarded as part and parcel of research in such a complex field as education. It is important to stress the benefits of the complementary nature of qualitative and quantitative approaches in getting to the truth and to recognise the reliability issues that can arise from the use of quantitative measures as well as qualitative ones. It could also be argued that where conflicts do arise, these are often more easy to rationalise through the analysis of qualitative data which can offer a rich narrative with in-built triangulation.

2.10. The Development of Testable Hypotheses

Following my review of the literature and the consideration of the factors outlined within the conceptual framework a number of testable hypotheses were derived from the general hypothesis that some students may be disadvantaged through the use of Web-based learning materials based on their cognitive predisposition (cognitive style) and/or approach to learning (deep or surface). These were variously tested during the first three case studies and were further supported through the qualitative methods employed during the fourth case study. The hypotheses were developed around two main influential factors, approach to learning and cognitive style and utilised data collected with Riding's Cognitive Styles Analysis (CSA) test and Biggs' Revised Study Process Questionnaire (R-SPQ-2F) for testing against dependent variables such as performance and perception. The hypotheses tested were:

1. Sensory cognitive style (verbaliser/imager) does not have an affect on students' performance in pre-test/post-test situations using the EDEC package.

2. Organisational cognitive style (wholist/analytic) does not have an affect on students' performance in pre-test/post-test situations using the EDEC package.

3. Sensory cognitive style (verbaliser/imager) does not have an affect on students' perceptions of the EDEC package.

4. Organisational cognitive style (wholist/analytic) does not have an affect on students' perceptions of the EDEC package.

5. Approach to learning (deep or surface) does not have an affect on the learner's performance in pre-test/post-test situations using the EDEC package.

6. Learning strategy (deep or surface) does not have an affect on the learner's performance in pre-test/post-test situations using the EDEC package.

7. Learner motivation (deep or surface) does not have an affect on the learner's performance in pre-test/post-test situations using the EDEC package.

8. Approach to learning (deep or surface) does not have an affect on students' perceptions of the EDEC package.

9. Learning strategy (deep or surface) does not have an affect on students' perceptions of the EDEC package.

10. Learner motivation (deep or surface) does not have an affect on students' perceptions of the EDEC package.

2.11. Students' Perceptions of EDEC

While the development of learning profiles allowed me to explore the effects that cognitive style and approach to learning had on students' behaviour and performance during their of the EDEC package, I was also interested in relating this to their perceptions of the package and the role of cognitive style and approach to learning in influencing these perceptions. Bruner (1996) succinctly observed the need for education and learning to, *'go beyond...information...to* *figure things out'*. Informed insight into the perceptions of the learner can go some way to identifying matches or mismatches between the actual learning which is taking place and the learning outcomes set. When triangulated with other data collection methods such as performance, confidence, observation etc., the researcher has the opportunity to gain a powerful insight into the factors that affect learning.

Shaw and Marlow's (1999) study of student attitudes towards the use of learning technologies demonstrated the importance of considering perceptions and attitudes, when evaluating such resources. They showed for example that the introduction of learning technologies can have a deleterious impact on student attitudes and perceptions if the intervention is not effectively embedded into the wider curriculum.

2.12. The Assessment of Resource Preference

Since cognitive predisposition may have an impact on the learner's perception of particular learning resources and instructional preference, I wished to be able to evaluate students' general resource preferences alongside their use of the EDEC package. The careful integration of new resources such as EDEC into the learning environment was a theme that recurred during my review of the literature (Laurillard, 1993, Felder, 1988, 1995, 1996, Zywno, 2000 and 2002, Doughty et al, 1995, Draper et al, 1996, Curry, 1983). Although there has been a fair degree of research into students' use of particular resources, few studies have considered this in the context of the students' wider resource preferences. The Teaching with Independent Learning Technologies (TILT) team at the University of Glasgow had previously used a Learning Resource Questionnaire (Brown et al, 1996) to evaluate students' resource preferences and I decided to utilise the questionnaire to gain an insight into where the EDEC package stood in the context of the students' overall resource preferences. The questionnaire had previously been used to investigate resource related study strategies as well as deficiencies in the teaching resources provided. It was included within a larger composite questionnaire which was also used to determine the students' approach to learning through Biggs' Revised Study Process Questionnaire (R-SPQ-2F) and their perceptions of the EDEC package.

2.13. The Assessment of Student Performance and Confidence

Pre/post tests were used at a number of times during the course of the research. These took the form of short quizzes that were derived from the content of the EDEC modules which made up each block of learning. The aim of each test was to test for students' prior knowledge of a particular topic (pre-test) and correlate this with their attainment after exposure to the learning material through the post-test. In order to be consistent throughout, each pre-test and post-test were always identical. Great care was taken prior to each pre-test that no material covered by the test itself was duplicated by the lecturer, thus contaminating the validity of the test itself. The questions chosen for each test were in multiple-choice format and were deliberately designed for completion without the need for support through calculators, which may also have given rise to validity issues.

As a means of assessing students' confidence in specific tasks and learning objectives, confidence logs were utilised on a number of occasions during the course of the research. Although typically used before and after exposure to learning material, practical issues encountered during the research dictated that this was not always possible. On these occasions, the confidence log was administered after exposure to the learning material and was validated through other means such as observation and student interview. While care was required in the analysis of responses to confidence logs since they do not test knowledge acquisition directly, they have proved a useful diagnostic research tool in this research, when supported by other instruments.

2.14. Observation of Students Using EDEC

Since the ethos of the research was directed towards a mixed-methods approach, as many opportunities as possible were sought for the observation of student activity and discussion with students during the activity where appropriate. These observations and the associated opportunity to take detailed notes acted as an excellent tool for corroboration and support of the other research methodologies used. Frechtling and Sharp (1997) highlighted a number of advantages and disadvantages of observation in research studies (Table 8).

Advantages and disadvantages of observations	
Advantages	▪ Provide direct information about behaviour of individuals and groups ▪ Permit evaluator to enter into and understand situation/context ▪ Provide good opportunities for identifying unanticipated outcomes ▪ Exist in natural, unstructured, and flexible setting
Disadvantages	▪ Expensive and time consuming ▪ Need well-qualified, highly trained observers; may need to be content experts ▪ May affect behaviour of participants ▪ Selective perception of observer may distort data ▪ Investigator has little control over situation ▪ Behaviour or set of behaviours observed may be atypical

Table 8

All observations were carried out during timetabled EDEC sessions, except in the case of the fourth case study. Observation logs were used as a means of recording data (see Appendices B, J and Q). The observation of students' use of the EDEC interface was particularly important to the evaluation of the effectiveness of the static, animated and interactive elements within the package. The use of checklists based on a template which was developed as part of the HEFCE funded Teaching and Learning Technology Programme (TLTP3) – Key Skills On-line initiative was explored as a means of standardising the layout and structure of each observation and while this proved useful in standardising the format of data, there was a degree of disadvantage in their lack of responsiveness to the evolving nature of each observational session.

2.15. Interviews with Students and Staff

A number of semi-structured interviews were carried out with relevant stakeholders as the research progressed. The degree of structure of the interviews was largely defined by the environment in which it was conducted and with whom. In the case of resource developer and teaching staff these were carried out in a formalised manner, with the intention being that a number of structured questions would be addressed through the course of each interview. The interviewing of students tended to have a less formal structure. This was largely due to the fact that access to students was always within timetabled sessions and care had to be taken so as not to disrupt the students' learning. These informal interviews proved to be useful however in supporting the dynamic process of observation as it progressed. They were particularly useful in clarifying or expanding upon ambiguous or confusing observations as they occurred and provided contextual data during the fourth case study where the students' discussed their use of another computer based resource.

During the third case study focus groups were utilised as a means of gaining a more sensitive insight into students' attitudes and perceptions to the use of the EDEC material. These consisted of 15-20 minute sessions at the end of two of the EDEC sessions and were held with groups of around twelve students. As well as providing useful data the sessions proved popular with the students themselves. The relaxed atmosphere that was engendered throughout the focus groups allowed me to informally explore areas of the students' learning in a manner which proved more sensitive than some other methods. They also provided an opportunity to explore observations made during each session with all students and therefore acted as an excellent validation tool.

2.16. The Use of Think-aloud During the Fourth Case Study

The use of verbal protocol (through think-aloud) as a qualitative evaluation tool was intended to be the prime means of data collection within the fourth and final case study. It was envisaged that this would provide an opportunity for rich contextualisation of the learning observed through the first three case studies. It was intended that carrying out a small number of think-aloud sessions would benefit the research overall in providing a deeper underpinning of the learning associated with the use of EDEC.

Think-aloud sessions have been used widely as a means of exploring a subject's mental process through verbalising of those processes. The validity and reliability of think-aloud in providing a window into the intricacies of a subject's unconscious processing however demands a degree of caution on the part of the researcher with regards to completeness of data and its use beyond illuminatory reporting. Ericsson and Simon (1984) stressed that the usefulness of think-aloud may to a large extent be determined by one's viewpoint, be it behaviourist or rationalist. They highlighted a number of issues that would require addressing by proponents, before verbal protocols would be regarded as valid objective research data. These were:

1. The need to respond to psychologists' doubts regarding the suitability of verbalisation as 'scientific' data.
2. Consideration of the processes that are required to transfer subjects' behaviours (whether verbal or not) into data.
3. The need to demonstrate that the encoding of behaviour into data can be carried out objectively, so that the resulting data will be 'hard' and not 'soft'.
4. Acknowledgement of the theoretical presuppositions that are necessarily embedded in the encoding process.
5. A means should be specified, which allows one to go backwards from the data to the behaviour and to inferences of the subjects' thought processes.

As a means of providing data that can be objectively analysed, verbal protocols provide a powerful tool for evaluating a subject's cognitive processes, and in particular the logical processes that take place in for example mathematical problem solving. The transcription of each think-aloud was carried out directly into the qualitative data analysis package, Transana with Jefferson transcription notation (Jefferson, 1984) being utilised to denote changes in tone and non-verbal sounds such as sighs. Screen-capture software was used to record all on-screen activity for the duration of each session. This enabled the matching of verbalisation with on-screen activity, such as cursor movement or data input, which could then be triangulated with my own observational notes. The benefit of the Transana interface is that it allows transcription to be synchronised with soundtrack and screen capture so that each can be considered simultaneously during data analysis.

2.17. Procedural Modelling

The development of a number of procedural models allowed me to investigate the conceptual process steps taken by each student during their interaction with different screen types as they progressed through the EDEC module. These models were based on an approach adopted by van Someren et al (1993, p.51), which combined psychological theory and task analysis in the process of developing a psychological model suitable for testing. To this end, existing theoretical models of problem solving behaviour (discussion of which, will follow in this section) were combined with information process-related tasks derived from an initial analysis of the EDEC package and students' information processing behaviour during its use. This was achieved through a 'grounded' theoretical approach (Glaser, 1982), where the comparative analysis of a subset of the students' verbal protocols was undertaken in conjunction with their associated screen capture and post-intervention interview data. This was used to confirm the original procedural models, with modifications made as coding issues emerged. The final models were developed using the NVivo qualitative analysis software, to allow coding to take place against verbal protocols, screen capture and interview data. It had been anticipated that the hypothetical models developed may require a further degree of post-analysis refinement in order to establish final working models which depicted the actual processing stages followed by the students as they interacted with different screen types. Table 9 outlines the four hypothetical procedural models that were developed alongside their associated screen type.

Model No.	**Model Process**	**Description**
1	Read text – orientate – reflect	Screens where physical interaction between the subject and the screen was not anticipated beyond the reading of text and/or review of static images.
2	Read text – orientate – process animation –reflect	Screens where subjects were expected to review a concept through the reading of text and review of animation.
3	Read text – orientate – analyse concept – test concept – reflect	Screens where subjects were expected to review a concept and then interact with the package to consolidate their understanding of the concept.
4	Read text – orientate – analyse concept – calculate - test concept - reflect	Screens where subjects were expected to carry out a calculation and input an answer directly to the package.

Table 9

In developing the procedural models, a degree of consideration was given to the literature on problem solving since there was an obvious relationship between the processing of information through media and the cognitive processes relating to conceptual problem solving. A number of models were distilled by Chiew and Wang (2004) who identified seven different approaches to problem solving. These were:

- **Facts** – Using direct solution path without much searching effort.

- **Hill climbing** – Make any move that approaches closer to the problem goal.
- **Working backward** – Frequently used in solving algebra and geometric proofs.
- **Algorithm application** – Using a given and well defined solution to a problem.
- **Exhaustive search** – Using a systematic search for possible solutions.
- **Heuristic approaches** –
    - **Rule of thumb**: selective search of a portion of solution space.
    - **Means-ends heuristic**: Solving sub-problems of the whole problem.
    - **Brainstorming**: A heuristic technique of finding possible solutions.
- **Analogy approach** – Using previous solutions to solve existing problem.

The cognitive steps involved in problem solving can be traced as far back as Plato, however Wallas (1926) went some way to defining the process of problem solving. His definition incorporated four phases,

1. ***Preparation:*** Defining the problem.
2. ***Incubation***: Subconsciously thinking about the problem prior to solving.
3. ***Inspiration***: Sudden insight into potential solutions.
4. ***Verification***: Checking the solution for correctness.

Other models of processing behaviour such as that developed by Polya (1957) included the same general elements as Wallas, although these models could be criticised as implying a linear approach to problem solving with no provision for the initiation of return loops as evidenced in the students' behaviour during this research. Newell and Simon (1972) developed a more complex approach that was based on computational modelling of the process. Their *'General Problem Solver'* theory mapped human behaviour to computer simulation and more explicitly included provision for return loops within the process. The nature of the theory did however limit its application beyond well-defined problems such as logic and geometry. Chiew and Wang took the modelling of problem solving a stage further with their attempt to develop a 'formal description' of problem solving which culminated in the development of a behavioural flowchart which included the provision for return loops dependant upon the learner`s reflection on key stages in the process.

My use of verbal protocol analysis during the final case study was intended to allow the evaluation of each student's behaviour with regard to the procedural models and importantly, with regard to their initiation of return loops during problem solving. This provided an insight into which processing phases were more likely to result in the initiation of a return loop and the point of return in the process overall which could be related to the use of particular media.

2.18. The Use of NVivo for the Analysis of Verbal Protocols

The software package NVivo was employed for the analysis of both verbal protocols and post-EDEC interviews. Each verbal protocol was coded against procedural nodes within NVivo in line with the hypothetical models outlined previously. A number of additional 'free' nodes were also developed in order to allow the coding of fragmentary factors such as problems with the user interface that would not be considered as part of the procedural models.

2.19. Considerations for Validity and Reliability of Data

The reliability of the instruments used in data gathering and of the data itself was rigorously considered during the selection of instruments and methodological approaches to the research. This was particularly important where statistical analysis was planned (Mogey, 1998). To this end, only instruments that could demonstrate an appropriate level of reliability were chosen for the collection of data (based on Cronbach's alpha coefficient). The situated nature of the research necessitated a pragmatic approach to the gathering of data during the first three case studies due to the vagaries of each individual learning environment. Although a consistent approach to the collection of data was employed where possible, there were occasions where it became impractical to use a particular instrument or instruments. This was generally due to time constraints or constraints put in place by the course lecturer.

Although the use of think-aloud is now widely accepted as a tool for gathering rich qualitative data, some researchers still regard them as being problematic in terms of validity and reliability. Van Someren et al (1994) highlighted a number of areas that may be open to criticism, including:

1. Invalidity due to disturbance of the cognitive process
2. Invalidity and incompleteness due to memory errors
3. Invalidity due to interpretation by the subject
4. Incompleteness due to synchronisation problems
5. Invalidity due to problems with working memory

While these issues may raise concerns among some researchers, it was felt that the benefits of using think-aloud as a means of gathering data for the fourth case study were offset by the complementary methods employed, which gave a measure of validity through triangulation. It was assumed that each sample was representative of the wider population in each of the case studies since each sample consisted of the entire cohort, which was available for the study. It was also assumed in each case that the learning intervention under evaluation was being delivered to the samples for the first time, thus eliminating reliability problems in using some instruments through prior knowledge on the part of the students.

The perceptions questionnaire that was administered to all of the students across each of the four case studies was analysed for reliability using Cronbach's alpha test before administration. The reliability coefficient was computed to be 0.8352 which would generally be regarded as providing a high degree of reliability. Similarly, the R-SPQ-2F was checked for reliability before its use. Biggs, Kember and Leung's (2001) testing of the instrument demonstrated a Cronbach's alpha coefficient of 0.7203.

2.20. Conclusions

While this research study was initially aimed at gaining an insight into the role of cognitive style and approach to learning on students' behaviour using the EDEC package, the conclusions that I have drawn from the literature have tended to dissuade me from the argument that teaching should be matched to the individual learner. This is largely based on the conflicting findings of the studies considered during the review of literature and the complexity of the role of personality on performance and perceptions of the learning environment. This is not to say that the educator should not consider good practice in the delivery of their courses as work on problem based and active learning in the engineering domain has shown. It does however suggest to me that the development of a rich and varied learning environment may be more important than the over-consideration of individual traits and styles. An emphasis on the appropriate and effective integration of Web-based resources would seem a more fruitful approach to curriculum development than those who wish to promote curriculum at the micro level which purports to adapt to the needs of the individual learner.

While there is a myriad of educational paradigms available to the researcher in a sector that is prone to trends, it is evident that the main elements of good theory and practice fill a common ground which transcends the individual. When we consider the works of educational theorists we can identify common factors and relationships in their research, but perhaps more important is their intent to consider the learning environment with regards to the needs of the learner and the promotion of effective learning. It is important to gain an understanding of the balance required in developing and delivering a rich and diverse curriculum, which also takes cognisance of stakeholder interactions within the learning environment. It is also important that any new learning intervention is evaluated in the wider context of the learning environment and the differences between individual learners if a rich learning experience is to be provided.

In developing my research strategy I determined that a number of specific tools would be required to give each strand of the study appropriate focus and continuity over the first three case studies and a more focused and qualitative approach taken in the design of the fourth case study. Where psychometric testing was required appropriately validated tests were utilised. To this end, both the Cognitive Styles Analysis (CSA) test and the Revised Study Process Questionnaire (R-SPQ-2F) were used since they had both gone through appropriate validation processes. These measures were supported by other data gathering tools such as questionnaire, observation, think-aloud, focus groups and interviews in order to facilitate triangulation of data where possible.

Chapter Three

Students' Use of EDEC - Case Study One

3. Overview of Case Studies

Four case studies were undertaken during the course of the research. Each of these was carried out at a separate university in the United Kingdom. While the intention was to apply a consistent experimental design for the first three quantitative studies, it became apparent that the instruments used would be required to fit the vagaries of each institution's particular circumstances and learning environment. This necessitated a pragmatic approach to the collection of data through negotiation with individual members of academic staff who were responsible for each of the courses. The flexible support provided by staff members at each institution, coupled with the opportunity to gather data in authentic learning situations did however compensate for any problems encountered with consistency of approach. The fourth and final case study employed quantitative methods to provide a detailed analysis of students' processing behaviour while using the EDEC package and was intended to support the quantitative data gathered through the other three case studies.

3.1. Case Study One

The sample for the first case study consisted of twenty-three second year undergraduate students from a university in southern England. The learning covered by the students during the study consisted of a single EDEC module called "Instrumentation Amplifiers". The session was timetabled to last for three hours. After a brief introduction to the session by the course lecturer, the students were expected to proceed through the module on a self-study basis. The module was intended to support lecture material that had been delivered beforehand, as well as to prepare the students for practical lab sessions which would immediately follow the module.

It was hoped that a profile of cognitive style could be developed for each student using Riding's Cognitive Styles Analysis test (CSA) during each of the four case studies. This however proved to be impracticable in this instance due to time constraints. The students were therefore profiled for approach to learning using Biggs and Kember's Revised Study Process Questionnaire (R-SPQ-2F). A summary of all the methods that were employed during the case study is shown in Table 10.

Area of Investigation	Methodologies
Student learning using EDEC	Observation log Student questioning
Approach to learning	Revised Study Process Questionnaire (R-SPQ-2F)
Student perceptions of the EDEC package	Questionnaire
Learning resource preference	Learning Resource Questionnaire

Table 10

3.2. Outline of Hypotheses

Based on the general hypothesis that certain groups of students may be disadvantaged by the method of delivery of media within the EDEC resource, a number of specific hypotheses were developed. These were intended to act as a focus for the testing of students' approach to learning against their perceptions of the resource. The hypotheses tested during the case study were:

1. Approach to learning (deep or surface) does not have an affect on students' perceptions of the EDEC package.

2. Learning strategy (deep or surface) does not have an affect on students' perceptions of the EDEC package.

3. Learner motivation (deep or surface) does not have an affect on students' perceptions of the EDEC package.

3.3. Student Perceptions

In order to gain an insight into the students' perceptions of the EDEC resource, and computers and the Internet more generally, a questionnaire was administered to the sample (Appendix A). It explored the following categories of student perceptions:

1. Learnability of the EDEC interface
2. Navigability of the EDEC interface
3. Quality of the EDEC interface
4. Graphic and interactive elements
5. Overall perceptions of EDEC
6. Computers and Internet

The results from the first section, learnability, as shown in Table 11 indicated that respondents had no real difficulty with the clarity of the instructions provided by the EDEC package and therefore quickly became familiar with the system (20 respondents agree/strongly agree). The only area of concern expressed by the students was with regard to the help offered by the system when they became confused. In this case seven of the respondents felt that the system didn't help them when they got confused compared with only four who felt that it did.

Results of Learnability of EDEC interface – Frequency of Responses (n=21 or 22)

Learnability	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I could follow the instructions clearly.	0	0	2	11	9
I quickly became familiar with the system.	0	1	1	6	14
Parts of the system were difficult to use.	5	10	3	3	1
The instructions on screen were sufficient when needed.	0	1	7	13	1
The system helped me if I got confused.	3	4	10	2	2

Table 11

Responses to the navigability of the interface and the general structure of the package indicated that the students were generally comfortable with the EDEC system and how to move through the module. It can be seen from Table 12 that most respondents were clear on where they were at any given time during the module. Almost all of them were also clear on how to navigate through it.

Results of navigability of EDEC interface - Frequency of Responses (n=22)

Navigability	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
It was clear to me where I was in the system.	1	2	7	6	6
It was clear how to move through the system.	0	0	1	14	7
I think that the system is generally well structured.	0	1	4	12	5

Table 12

When asked to give their perceptions of the quality of the EDEC interface (Table 13), responses were again generally positive towards the presentation of information within the package, the use of language and the interface more generally. The only areas of concern apparent from the results came from respondents' perceptions of their ability to retrieve the information they needed from the system quickly, with ten of the twenty-two students responding neutral. Six students also agreed/strongly agreed that there was too much information on each screen for them to remember. Respondents gave a high approval rating to the actual content of the EDEC module, with nineteen disagreeing/strongly disagreeing that there was too much information that they didn't need to know within the content.

Results of Quality of EDEC interface - Frequency of Responses (n=21 or 22)					
Quality	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I found that the information was presented consistently.	0	1	4	12	4
It was obvious how to use the icons (buttons).	0	0	0	11	10
The language was clear.	0	0	2	11	8
I could easily read from the screen.	1	0	3	6	12
The screen colour did not interfere with my reading.	1	0	1	8	12
I got what I wanted from the system quickly.	1	0	10	10	1
Overall, the system had an attractive presentation.	0	2	4	8	8
There was too much information on each page for me to remember.	2	8	6	5	1
There was too much information which I didn't need to know.	4	15	3	0	0

Table 13

In evaluating perceptions of the graphic, animated and interactive elements the students were asked a number of questions which were supported by observation and questioning as they proceeded through the module. A summary of the findings from the questionnaire are shown in Table 14.

Evaluation of graphic, animated and interactive elements - Frequency of Responses (n=22)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I thought that the graphics were clear and helpful.	0	1	4	9	8
I thought that the interactive elements were difficult to find.	5	9	5	2	1
I found the animated elements too fast.	3	10	6	2	1
I felt that the animated elements would have been better if I could control speed and stop/start.	4	4	9	1	4
The use of images to support text was useful.	0	0	1	9	12

Table 14

The students questioned almost universally indicated that they found the graphics helpful to their learning. Some however expressed a wish to be able to control the speed of animated elements by being able to stop and start them at will in order to maximise the opportunity to process the visual information. When a number of perceptions variables were analysed comparatively a strong relationship was observed between the students' perceptions of the speed of the animated elements and their ability to easily find the interactive elements in the package (Table 15).

Comparison of the Students' Perceptions of the Speed of Animations and Difficulty in Finding Interactive Elements

			I thought that the interactive elements were difficult to find.
Spearman's rho	I found the animated elements too fast.	Correlation Coefficient	.689**
		Sig. (2-tailed)	.0004
		N	22

**. Correlation is significant at the 0.01 level (2-tailed).

Table 15

While this finding indicated that those students who found the animations too fast were more likely to have difficulty in identifying interactive elements, subsequent analysis showed that this relationship could not be attributed to approach to learning as determined from the R-SPQ-2F results (see Table 34).

When asked for their overall impressions of the EDEC system, the responses from students were typically positive. The results from shown in Table 16 indicate that they were able to separate their perceptions of the package from their resource preferences more generally as demonstrated in their responses to the Learning Resource Questionnaire (see section 5.4 of this chapter).

Overall student perceptions of EDEC system - Frequency of Responses (n=22)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Overall, I liked using the system.	0	2	3	15	2
I would use this system again in my studying.	0	1	6	10	5
I would recommend the system to other students.	0	2	1	9	10

Table 16

Overall, the responses to the questionnaire indicated that the students were generally positively disposed to the EDEC package as a vehicle for learning. They identified no real problems in navigating through the system and found it well structured. In terms of the students' ability to process information on screen, there were a number of students who felt that there was too much information on single screens to allow effective processing to take place. Many of the foreign students within the cohort expressed a preference for this type of Web-based learning resource over the traditional, orally delivered lecture format due to the fact that they had a better opportunity to process textual information without the hindrance of extraneous use of colloquialism or dialect problems being present. This finding contradicted the overall responses to the Learning Resource Questionnaire where lectures came out most strongly in terms of usefulness (see Table 18).

In order to broaden the context of the evaluation from EDEC specifically to students' more general use of computers and the Internet, a number of questions were asked. These were intended to gain an insight into the importance of the computer and the Internet to students' study as well as evaluating their perceptions of learning through a computer more generally. It can be seen from Table 17 that computer use and the Internet are vital components of student activity and learning, with nineteen and eighteen of the students using a computer and the Internet most days respectively. A high proportion of respondents also indicated that they enjoyed learning through computer packages (seventeen respondents agree/strongly agree), indicating that they were generally positively disposed to learning through computers which concurs with their general perceptions of EDEC.

Computer and Internet perceptions - Frequency of Responses (n=22)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I like to learn using computer packages.	0	2	3	11	6
The Internet is very useful to my learning.	0	1	4	5	12
	Less than once a month	**Around once a week**	**3 or 4 time a week**	**Most days**	**Never used one**
How often do you use a computer?	0	1	2	19	0
How often do you use the Internet?	0	0	4	18	0

Table 17

3.4. Learning Resource Questionnaire

The Learning Resource Questionnaire was administered at the end of the EDEC session in order to evaluate student perceptions of the EDEC package alongside the other resources that they could encounter during this particular block of learning. The results shown in Table 18 clearly indicated that lectures were still regarded as the most important resource in their learning. The importance of lectures and lecture notes, when compared with the EDEC materials indicated that the learning gained through use of the EDEC package may have been perceived as supporting the core learning provided by the lectures. This observation was supported during discussion with the lecturer where he confirmed that the EDEC materials were intended to provide support to learning which was to a degree duplicated during lectures.

Usefulness of resources – Frequency of Responses (n=21 or 22)					
	Useless	Not very useful	Useful	Vital	Not sure
Lectures	0	0	4	17	1
Textbook(s)	0	1	14	7	0
EDEC computer package	0	1	17	3	1
Own notes from lectures/labs	0	1	10	11	0
Borrowed notes from someone else	6	10	5	0	1
Discussions with tutor/lecturer	0	0	15	5	1
Discussions with other students	2	1	17	2	0

Table 18

3.5. Approach to Learning

In order to determine whether students' approach to learning had a bearing on the students' use of and perceptions of the EDEC package, Biggs and Kember's Revised Study Process Questionnaire (R-SPQ-2F) was administered. The results from the questionnaire provided a profile for each student in terms of deep or surface approach as well as two further subcategories, deep/surface strategy and deep/surface motivation. Tables 19 to 21 give a breakdown of each of these categories for the sample.

	Deep/Surface approach
	Number of students
Deep approach	19
Surface approach	3

Table 19

	Deep/Surface motivation
	Number of students
Deep motivation	19
Surface motivation	2
Equal	1

Table 20

	Deep/Surface strategies
	Number of students
Deep strategy	15
Surface strategy	6
Equal	1

Table 21

It can be seen from the tables that the sample of students was predominantly made up of deep learners, although the level of profundity varied for individual students. This proportion remained reasonably consistent for learner motivation. however it dropped a little for learning strategy, with a greater proportion of students identified as having a surface strategy.

3.6. Student Perceptions and Approach to Learning

Since approach to learning may have had an impact on the students' perceptions of the EDEC package, the data collected from Biggs' R-SPQ-2F was tested against the students' responses to the perceptions questionnaire. The three hypotheses that were tested were based on the main approach to learning category within the R-SPQ-2F and the two sub-categories, strategy and motivation. These were:

1. Approach to learning (deep/surface) does not have an effect on students' perceptions of the EDEC system.

2. Learning strategy (deep/surface) does not have an effect on students' perceptions of the EDEC system.

3. Learner motivation (deep/surface) does not have an effect on students' perceptions of the EDEC system.

The analysis utilised the perceptions categories outlined in section 3.3 which were tested against the students' responses to the R-SPQ-2F. The sample for the study consisted of all 22 students and Spearman's test for bivariate correlation was used due to the non-parametric nature of the data.

As a precursor to the testing of the students' perceptions of EDEC, a general comparison of their perceptions of computer packages as learning tools and the R-SPQ-2F results was made (Table 22). The results indicated a significant positive relationship between the students' perception of computer packages as learning resources and R-SPQ-2F score on the deep approach and deep strategy scales (corr. coeff. = 0.512, $p=0.015$ and corr. coeff. = 0.467, $p=0.028$ respectively).

Comparison of R-SPQ-2F Results and the Students' Perceptions of Learning Using Computer Packages

			I like to learn using computer packages.
Spearman's rho	Deep approach	Correlation Coefficient	.512*
		Sig. (2-tailed)	.015
		N	22
	Surface approach	Correlation Coefficient	-.282
		Sig. (2-tailed)	.203
		N	22
	Deep strategy	Correlation Coefficient	.467*
		Sig. (2-tailed)	.028
		N	22
	Surface strategy	Correlation Coefficient	-.236
		Sig. (2-tailed)	.290
		N	22
	Deep motive	Correlation Coefficient	.384
		Sig. (2-tailed)	.078
		N	22
	Surface motive	Correlation Coefficient	-.348
		Sig. (2-tailed)	.112
		N	22

*. Correlation is significant at the 0.05 level (2-tailed).

Table 22

When the individual perceptions categories were tested against the R-SPQ-2F results a number of significant relationships were observed. Table 23 shows the comparison of the students' perceptions on the learnability of EDEC against their R-SPQ-2F scores. The results demonstrated a number of significant relationships between deep approach, strategy and motivation and perception variables indicating a more positive perception among students who tended to score highly on the deep scales. The significant negative correlation observed between surface motivation and the students' perception of the sufficiency of instructions during their use of EDEC reinforced the general relationship observed between positive perception and deep tendency.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Learnability of EDEC

			I could follow the instructions clearly.	I quickly became familiar with the system.	Parts of the system were difficult to use.	The instructions on screen were sufficient when needed	The system helped me if I got confused.
Spearman's rho	Deep approach	Correlation Coefficient	.707**	.389	-.154	.039	.642**
		Sig. (2-tailed)	.0002	.074	.495	.863	.002
		N	22	22	22	22	21
	Surface approach	Correlation Coefficient	-.193	-.098	.292	-.363	-.368
		Sig. (2-tailed)	.391	.664	.187	.097	.100
		N	22	22	22	22	21
	Deep strategy	Correlation Coefficient	.686**	.401	-.104	-.218	.392
		Sig. (2-tailed)	.0004	.064	.646	.331	.079
		N	22	22	22	22	21
	Surface strategy	Correlation Coefficient	-.248	-.152	.416	-.302	-.358
		Sig. (2-tailed)	.267	.500	.054	.172	.111
		N	22	22	22	22	21
	Deep motive	Correlation Coefficient	.537**	.164	-.209	.234	.654**
		Sig. (2-tailed)	.010	.467	.349	.295	.001
		N	22	22	22	22	21
	Surface motive	Correlation Coefficient	-.138	-.015	.090	-.553**	-.410
		Sig. (2-tailed)	.541	.947	.691	.008	.065
		N	22	22	22	22	21

**. Correlation is significant at the .01 level (2-tailed).

Table 23

The comparison between perception of navigability of EDEC and the R-SPQ-2F results demonstrated a clear and positively significant relationship between the deep strategy scale and the students' perceptions over each of the three variables (Table 24). However, unlike the previous category, this relationship did not translate significantly to the deep approach and motivation scales.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Navigability of EDEC

			It was clear to me where I was in the system.	It was clear how to move through the system.	I think that the system is generally well structured.
Spearman's rho	Deep approach	Correlation Coefficient	.341	.271	.355
		Sig. (2-tailed)	.120	.222	.105
		N	22	22	22
	Surface approach	Correlation Coefficient	.198	-.004	-.051
		Sig. (2-tailed)	.378	.986	.823
		N	22	22	22
	Deep strategy	Correlation Coefficient	.658**	.444*	.515*
		Sig. (2-tailed)	.001	.038	.014
		N	22	22	22
	Surface strategy	Correlation Coefficient	.188	.016	.033
		Sig. (2-tailed)	.403	.943	.886
		N	22	22	22
	Deep motive	Correlation Coefficient	.085	.040	.195
		Sig. (2-tailed)	.707	.861	.383
		N	22	22	22
	Surface motive	Correlation Coefficient	.243	.021	-.128
		Sig. (2-tailed)	.276	.927	.569
		N	22	22	22

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 24

There was little evidence of significance between either of the deep and surface scales and the students' perceptions of the quality of EDEC (Table 25). The most interesting finding observed related to the statement, *'I got what I wanted from the system quickly'*, which correlated significantly with the deep motivation scale. This finding may be linked to the self-study approach taken by the course lecturer to the use of EDEC, thus requiring a deeper commitment on the part of the student for learning to take place.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Quality of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I found that the information was presented consistently.	Correlation Coefficient	.521*	-.034	.549**	-.147	.429	.177
		Sig. (2-tailed)	.015	.883	.010	.524	.053	443
		N	21	21	21	21	21	21
	It was obvious how to use the icons (buttons etc.).	Correlation Coefficient	-.119	.411	.079	.340	-.183	.447*
		Sig. (2-tailed)	.609	.064	.733	.132	427	.042
		N	21	21	21	21	21	21
	The language was clear.	Correlation Coefficient	.289	.116	.347	.010	.160	.163
		Sig. (2-tailed)	.203	.615	.123	.965	.488	.480
		N	21	21	21	21	21	21
	I could easily read from the screen.	Correlation Coefficient	.404	.101	.420	.032	.328	189
		Sig. (2-tailed)	.062	.656	.052	.889	.136	400
		N	22	22	22	22	22	22
	The screen colour did not interfere with my reading.	Correlation Coefficient	-.092	.303	.162	.154	-.220	.414
		Sig. (2-tailed)	.683	.171	.472	.495	.324	.055
		N	22	22	22	22	22	22
	I got what I wanted from the system quickly.	Correlation Coefficient	.322	-.115	.077	-.162	.451*	-.150
		Sig. (2-tailed)	.144	.612	.735	.473	.035	.506
		N	22	22	22	22	22	22
	Overall, the system had an attractive presentation.	Correlation Coefficient	.316	-.044	.368	-.135	.273	.012
		Sig. (2-tailed)	.153	.847	.092	.551	.219	.957
		N	22	22	22	22	22	22
	There was too much information on each page for me to remember.	Correlation Coefficient	.008	.052	-.150	.159	.242	-.072
		Sig. (2-tailed)	.971	.818	.504	.480	.277	.750
		N	22	22	22	22	22	22
	There was too much information which I didn't need to know.	Correlation Coefficient	.159	-.199	-.051	-.116	.253	-.282
		Sig. (2-tailed)	.481	.375	.823	.608	.256	.203
		N	22	22	22	22	22	22

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 25

Although some students had expressed problems with the amount of information that they were required to process and remember from each screen (see Table 13), the results indicated that these were not related to approach to learning.

With regard to the graphic, animated and interactive content within the EDEC module, there were no observable relationships with either deep or surface tendency and perceptions variables leading one to presume that any problems with the processing of information experienced by the students were independent of approach to learning (Table 26). These findings generally concurred with the positive perceptions of these elements obtained through discussion with the students during their use of the package.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Graphic, Animated and Interactive Elements of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I thought that the graphics were clear and helpful.	Correlation Coefficient	.134	.226	.048	.143	171	225
		Sig. (2-tailed)	.553	.312	.831	.525	447	.315
		N	22	22	22	22	22	22
	I thought that the interactive elements were difficult to find.	Correlation Coefficient	-.184	-.070	-.051	.025	-.154	-.038
		Sig. (2-tailed)	.413	.759	.821	.913	.493	.868
		N	22	22	22	22	22	22
	I found the animated elements too fast.	Correlation Coefficient	-.194	.230	-.293	.284	-.023	.138
		Sig. (2-tailed)	.386	.304	.185	.200	.918	.539
		N	22	22	22	22	22	22
	I felt that the animated elements would have been better if I could control speed and stop/start.	Correlation Coefficient	.031	.116	.026	.152	-.039	.079
		Sig. (2-tailed)	.890	.606	.907	.500	.864	.726
		N	22	22	22	22	22	22
	The use of images to support text was useful.	Correlation Coefficient	-.081	.074	.225	.000	-.302	.214
		Sig. (2-tailed)	.720	.744	.314	.999	.172	.338
		N	22	22	22	22	22	22

Table 26

The significant correlation discussed earlier between deep strategy and the students' perception of computer packages for learning (see Table 22) translated to the students' overall perceptions of EDEC with a similarly significant relationship observed between deep strategy and responses to the statement, *'Overall I liked using the system'* (corr. coeff. = 0.466, p=0.029) (Table 27). The general tendency towards significance between perception and deep strategy indicated a stronger general relationship for this particular dimension over the other deep categories (approach and motivation).

Comparison of R-SPQ-2F Results and Students' Overall Perceptions of EDEC

			Overall, I liked using the system.	I would use this system again in my studying.	I would recommend the system to other students.
Spearman's rho	Deep approach	Correlation Coefficient	.325	.144	.276
		Sig. (2-tailed)	.140	.522	.214
		N	22	22	22
	Surface approach	Correlation Coefficient	.040	.047	.119
		Sig. (2-tailed)	.860	.835	.598
		N	22	22	22
	Deep strategy	Correlation Coefficient	.466*	.309	.390
		Sig. (2-tailed)	.029	.161	.073
		N	22	22	22
	Surface strategy	Correlation Coefficient	-.052	.061	.063
		Sig. (2-tailed)	.817	.789	.779
		N	22	22	22
	Deep motive	Correlation Coefficient	.145	-.048	.169
		Sig. (2-tailed)	.519	.830	.452
		N	22	22	22
	Surface motive	Correlation Coefficient	.124	-.019	.136
		Sig. (2-tailed)	.582	.933	.546
		N	22	22	22

*. Correlation is significant at the .05 level (2-tailed).

Table 27

The analyses generally indicated a positive relationship between student perceptions of EDEC and a deep tendency over a number of variables. This was particularly the case with perception variables relating to the students' orientation through the package (learnability and navigability). Of the three deep learning scales, strategy appeared to link most strongly with a positive overall perception of the EDEC package and the use of computers to support learning in general. With regard to the graphic, animated and interactive elements within the EDEC module that was used there was no evidence of a significant relationship between either deep or surface tendency indicating that the choice of media and its delivery was not linked to perception. This may indicate that the commitment required by the students to engage with EDEC on a self-study basis without face to face contact with the course lecturer had more of a role to play in determining perception than the form of delivery. This conclusion was supported by the results of the Learning Resource Questionnaire where lectures and discussion with the course lecturer scored highly in terms of usefulness.

While not statistically significant, the generally negative relationship observed between surface tendency and the students' perceptions would lead to the conclusion that approach to learning did have an impact on the students' perceptions of EDEC. The significant nature of the relationship between a number of perceptions variables and the results from the R-SPQ-2F in the three deep scales indicated that approach and strategy in particular had an affect on the students' perceptions of EDEC. Although this relationship was not observed over all perceptions variables the evidence would suggest a rejection of hypotheses 1 and 2 as outlined at the start of this chapter for some perceptions categories. While there was a degree of significance observed in the analysis of deep motive and perceptions variables, particularly in the 'learnability' category, the evidence of a relationship overall was not strong enough to suggest a rejection of hypothesis 3.

3.7. Student Comments

There was further evidence of the relationship between deep or surface learning tendency and perceptions of EDEC through the students' open comments on EDEC from the perceptions questionnaire (see Appendix C). An illustration of this came in the form of comments received made by the two students at the furthest ends of the deep/surface continuum based on their R-SPQ-2F results. Student 14, who scored highest in the three deep scales, approach, strategy and motivation commented,

> *"I find learning through internet very useful and more involved. The whole idea of computer based learning is one of the best things that I've seen the emerging technology bring about. Computer based learning is one to one and is bound to get you fully involved and familiar with what you are learning."*

While at the other end of the scale student 2 who had the lowest score across the deep scales indicated a more goal-orientated approach to EDEC where outcomes were referenced against time,

> *"The EDEC package is very helpful in my studies. The only problem is that, it is time consuming and quite boring sitting in front of the computer just clicking the mouse."*

Interestingly, the four students who scored the least in the deep scales covered by the R-SPQ-2F were the only ones to comment on the time taken to work through EDEC. There was an observable trend in the comments made by these students, becoming more positive the higher up the deep scale the students scored in the R-SPQ-2F. A number of students highlighted problems with note-taking during the module. Although they were provided with an accompanying workbook which had been developed in-house to support EDEC a number of them indicated that it did not provide enough space for additional note-taking. Student 3 who had the third lowest score on the deep scales provided an insight into his approach to EDEC and perhaps his studies in general.

> *"EDEC is a useful, however time-consuming package. I have tended to copy most notes and especially formulas. It would be more useful to work through without any note taking and then have a bulleted summary at the end of each section from which to take notes and formulas."*

His comment highlighted a goal-orientated approach to EDEC where he simply wished to gather knowledge in a surface manner for future regurgitation with little concern for the conceptual underpinning that EDEC was intended to provide through animated media.

3.8. Observations of the EDEC Session and Discussion with the Students

The lab that was used for the EDEC session was a rectangular room with computer provision for around 25 students. The general layout of this room is shown in Figure 16.

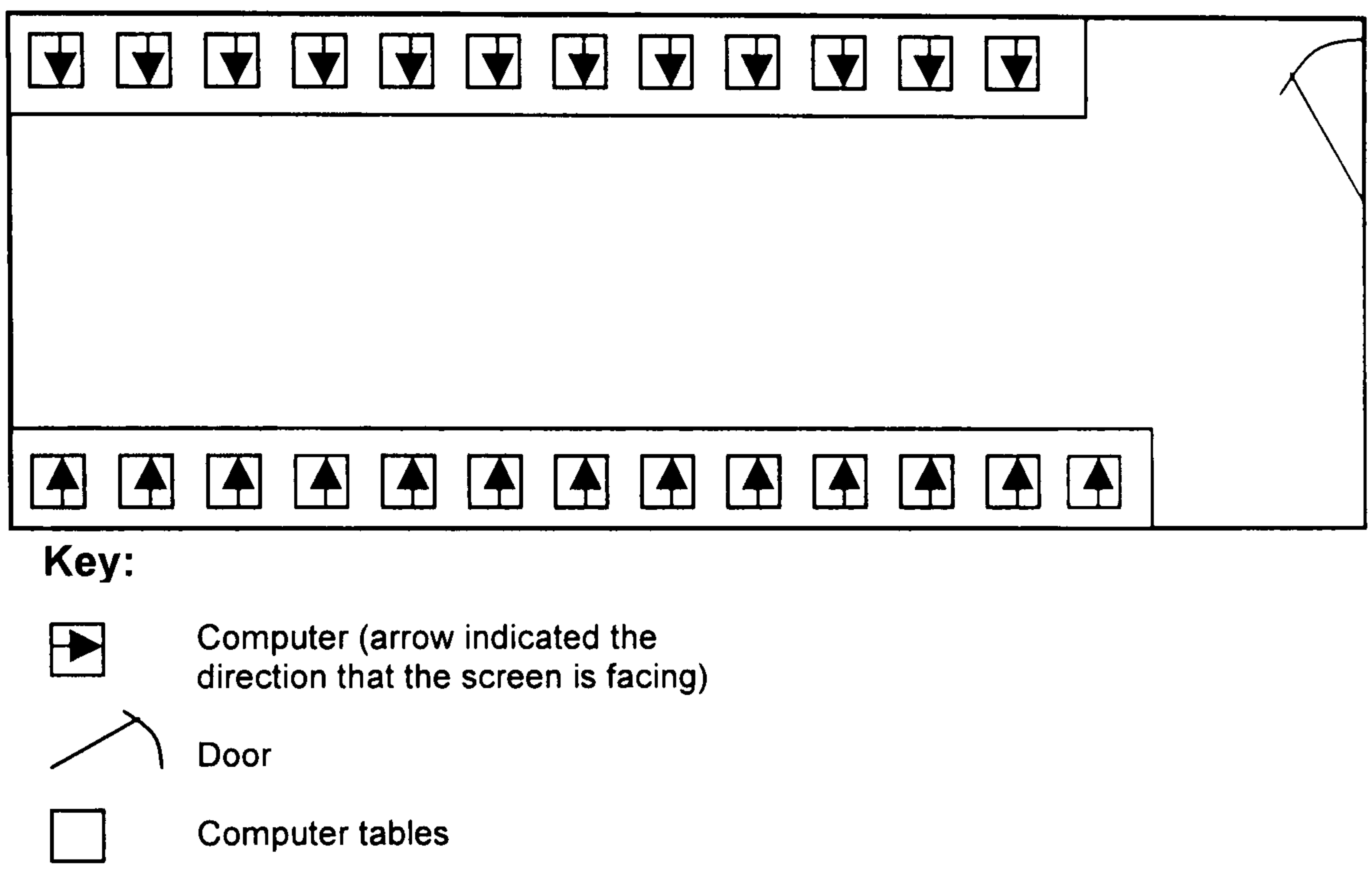


Figure 16

While there were enough computers in the lab to allow for individual study, students had the opportunity to collaborate with others if desired. It was observed that due to the fact that the two rows of computers were arranged to face in opposite directions that students tended to stick to interaction within their row, although there was a fair degree of interaction and co-operation in evidence.

At the start of the session I was introduced to the students by the course lecturer. This provided me with the opportunity to outline my role, a large part of which would entail the observation and questioning of students as they progressed through the EDEC module. It also provided me with the opportunity to put the students' at ease regarding my presence during the session. The lecturer, who would normally have been present to offer support, was largely unavailable for the session in order to *'allow me full access'* to the sample. Although the learning situation could be said to have been subject to the influence of myself and the other researcher present, care was taken to minimise any 'Hawthorne' effect, where the researchers may influence the responses of the students.

The session was timetabled to last for three hours, although students were not obliged to complete the full three hours. I was present for the duration of the session in order to allow observational notes (see Appendix B) and student responses to questions to be documented. All notes were taken manually. The students were generally observed to have used their accompanying notebooks for note-taking during the session, with some taking additional notes as required. When note-taking was discussed with a number of students, they linked them directly with the goal of passing exams. A number of students complained that there was insufficient space within the workbook for independent note-taking which tended to fragment them.

During their use of EDEC, there was clear evidence of a number of students taking a trial and error to interactive elements such as multiple choice questions, although there was also evidence of many students entering a reflective phase, typically at the end of their time on-screen which was coupled with note-taking.

Although most of the students expressed no difficulty with their processing of animated elements of the package there was some observational evidence of this. One student in particular expressed concern that the animations were confusing which may allude to problems experienced with the processing of information during them. A number of students highlighted the need to be able to control animations to allow effective processing to take place. This was particularly evident in the observation of note-taking during them which some students found difficult due to their pace and the inability to start and stop them as required.

The flexibility offered by EDEC was raised by a number of students who indicated that they would use the package at home of in halls of residence in support of their learning. None of those who had used the package off-campus during previous modules had encountered difficulty with accessing and using the material.

3.9. Discussion

The students were generally positive in their perceptions of the EDEC material. Evidence for this came from the questionnaire responses and was supported by general responses from students during discussion as well as my observation of them during the session. The learning environment was observed to have influenced the atmosphere inside the lab, which was relaxed and business-like. This was also the case with regard to the relationships and interaction of students, which was informal and supportive throughout. While the layout of the lab promoted cooperation among students which was generally limited to rows, it appeared to balance cooperation with individual student progress.

Although the students were predominantly categorised as deep learners through the R-SPQ-2F there was statistical evidence to suggest that their perceptions of the package was influenced by the profundity of approach to learning on the deep scales. This evidence was further supported by individual students' comments, which tended to be more positive, the deeper the learner.

The contingent of foreign students that made up around 50% of the cohort highlighted an unexpected benefit of the package in providing them with as much time as necessary to process language which was not native to them. A number of these students during discussion indicated that the package offered them benefits over traditional lectures, as they had more time to process language during their use of the package than would be the case in a traditional lecture setting.

Chapter Four

Students' Use of EDEC - Case Study Two

4. Introduction

The second case study involved a group of first year Electronics Engineering students at a university in northern England. The study took place on one day a week over a six-week period. The sample consisted of fifty-seven students in total, however attendance varied over the six-week period and therefore sample sizes for individual measures were typically reduced. The first three weeks of the study consisted of a one-hour lecture session which was followed by a three hour session covering a single EDEC module. During the final three sessions the students were intended to utilise the learning gained through the three EDEC sessions in a practical lab environment where they developed computer programmes using assembly language. An overview of the sessions and their duration is shown in Table 28.

	Description of Session
Week 1	Introductory lecture (1 hour) EDEC lab session (3 hours)
Week 2	Introductory lecture (1 hour) EDEC lab session (3 hours)
Week 3	Introductory lecture (1 hour) EDEC lab session (3 hours)
Week 4	Practical lab session (3 hours)
Week 5	Practical lab session (3 hours)
Week 6	Practical lab session (3 hours)

Table 28

4.1. Evaluation Methods

The methods employed during the evaluation were intended to create a learning profile for each student covering cognitive style and approach to learning and which could be tested against the students' perceptions of the EDEC package and performance during pre/post-testing. An observation log was kept for each of the six sessions in order to record the students processing behaviour during their use of EDEC and during the subsequent practical lab sessions. The observation logs included data collected through informal questioning of students as they progressed through each session. A full list of the methods used is outlined in Table 29.

Area of Investigation	Methodologies
Cognitive styles assessment	Cognitive Styles Analysis test (CSA)
Student learning	Pre/post test quizzes Observation logs Student questioning during sessions
Approach to learning	Revised Study Process Questionnaire (R-SPQ-2F)
Student perceptions of EDEC	Questionnaire
Student resource preferences	Learning Resource Questionnaire
Pedagogical issues	Course deliverer interview

Table 29

4.2. Outline of Hypotheses

Based on the general hypothesis that certain groups of students may be disadvantaged by the method of delivery of media during their use of the EDEC resource, a number of specific hypotheses were developed. These were intended to focus the analysis of quantitative data relating to students' cognitive style and approach to learning for testing against other variables such as performance and perception. The hypotheses tested during the case study were:

1. Sensory cognitive style (verbaliser/imager) does not have an affect on students' performance in pre-test/post-test situations using the EDEC package.
2. Organisational cognitive style (wholist/analytic) does not have an affect on students' performance in pre-test/post-test situations using the EDEC package.
3. Sensory cognitive style (verbaliser/imager) does not have an affect on students' perceptions of the EDEC package.
4. Organisational cognitive style (wholist/analytic) does not have an affect on students' perceptions of the EDEC package.

5. Approach to learning (deep or surface) does not have an affect on the learner's performance in pre-test/post-test situations using the EDEC package.

6. Learning strategy (deep or surface) does not have an affect on the learner's performance in pre-test/post-test situations using the EDEC package.

7. Learner motivation (deep or surface) does not have an affect on the learner's performance in pre-test/post-test situations using the EDEC package.

8. Approach to learning (deep or surface) does not have an affect on students' perceptions of the EDEC package.

9. Learning strategy (deep or surface) does not have an affect on students' perceptions of the EDEC package.

10. Learner motivation (deep or surface) does not have an affect on students' perceptions of the EDEC package.

4.3. The Introductory Lectures

The one-hour introductory lectures, which preceded the EDEC sessions were intended to briefly introduce the topic, cover housekeeping issues and reinforce the previous week's learning. They were also used to review any self-study questions from the previous week that had been given to the students via workbooks. The course lecturer took care not to invalidate any of the pre/post test quiz questions during these sessions.

Since the lecturer regarded the EDEC modules as being standalone and core to the learning of the theory covered, he did not spend any time covering learning that was intended to be covered through the package itself.

4.4. Background to the EDEC Modules

The EDEC modules that were used during this case study were developed within the institution itself. Each of the modules were in fact directly translated into the EDEC format from traditional lecture notes which had previously been delivered via overhead projector slides. An interview was carried out with the course lecturer in order to explore the rationale behind the course and the role of the EDEC modules in supporting the students' learning (Appendix D).

The learning aims of the EDEC modules were described during the interview as leading towards an understanding of how a computer works in terms of information processing and programming. The introductory nature of the modules was intended to support the second year syllabus, which was heavily reliant on knowledge of assembly language. The lecturer stressed that the EDEC interface was unsuitable for actual programming activity in assembly language, although the content was intended to provide a *'learning overview'* prior to practical labs which entailed programming tasks using assembly language.

When asked what steps had been taken to integrate the EDEC modules into the course overall, he indicated that it had never been his intention to fully integrate the material, with his primary aim being simply the replication of lecture notes. He highlighted a number of different timing and delivery combinations that had been used over previous years, it was indicated that the delivery of the EDEC modules as a three week block (one module per week), followed by a subsequent three week block for the practical labs, proved most effective.

The time savings for both students and teaching staff that had been gained through the use of EDEC were discussed during an earlier evaluation of the effectiveness of the package (Coleman et al, 1998). The lecturer indicated that the use of the EDEC materials had freed up time for more extensive practical lab sessions, which were viewed as being the primary learning outcome.

4.5. The EDEC Lab Sessions

Three EDEC modules were intended to provide students with a platform of knowledge in preparation for the practical lab sessions, culminating in an assessed assignment. Each student was expected to complete one EDEC module per three-hour session. The three modules used are shown in Table 30.

EDEC Modules	
Week 1	Number Systems
Week 2	Introduction to Computer Systems
Week 3	Introduction to Assembly Language

Table 30

The EDEC sessions were carried out in a large computer cluster, with each student working independently through the modules. Support was provided by the lecturer and two demonstrators. There were occasions when other students used the cluster for general computer work. Although three hours were timetabled for each session, the lecturer indicated that he anticipated students would generally be complete within two hours based on previous experience. While in previous years, students had been given responsibility for the time that they spent using the EDEC material, the lecturer indicated that a more structured and rigorous monitoring their use of EDEC was more conducive to learning.

4.6. The Learning Environment

During the interview with the course lecturer he had highlighted appropriate selection of resources and the physical learning environment as being his key considerations in promoting an effective learning experience. The use of a single, large computer cluster for the EDEC modules had allowed the students to work individually as against in pairs for previous years. The lecturer also highlighted the beneficial nature of the individual learning environment as opposed to paired, in allowing students to progress at a pace which was appropriate to their own needs. The cluster had two rooms consisting of a large main cluster suitable for around fifty students and a second smaller one that was suitable for around 14 students. This was situated on a mezzanine level above the large cluster. The computers were arranged as shown in Figure 17.

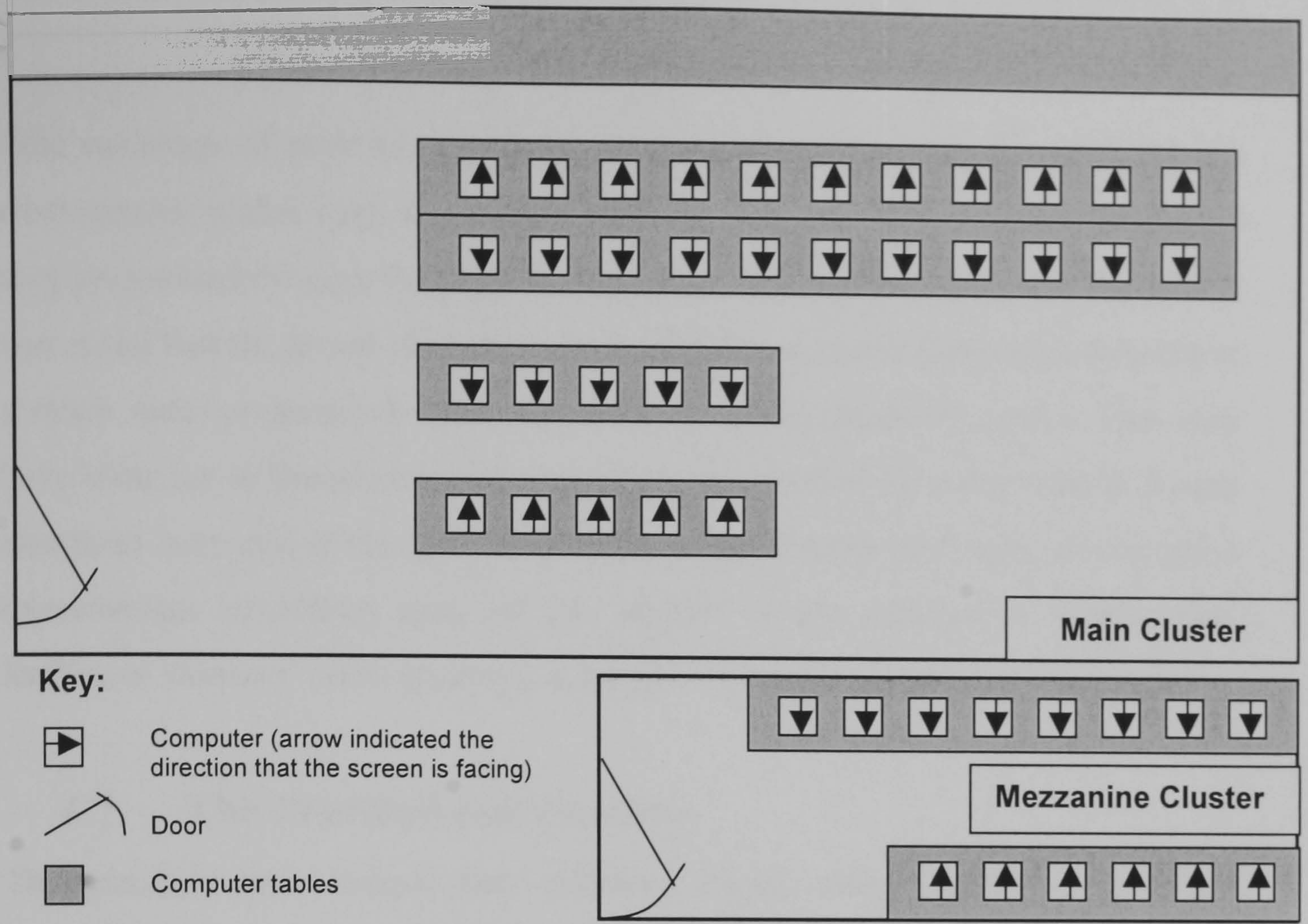


Figure 17

The lab in which the practical sessions took place was similar in size to the main computer lab and was all on one level. The layout of this lab can be seen in Figure 18.

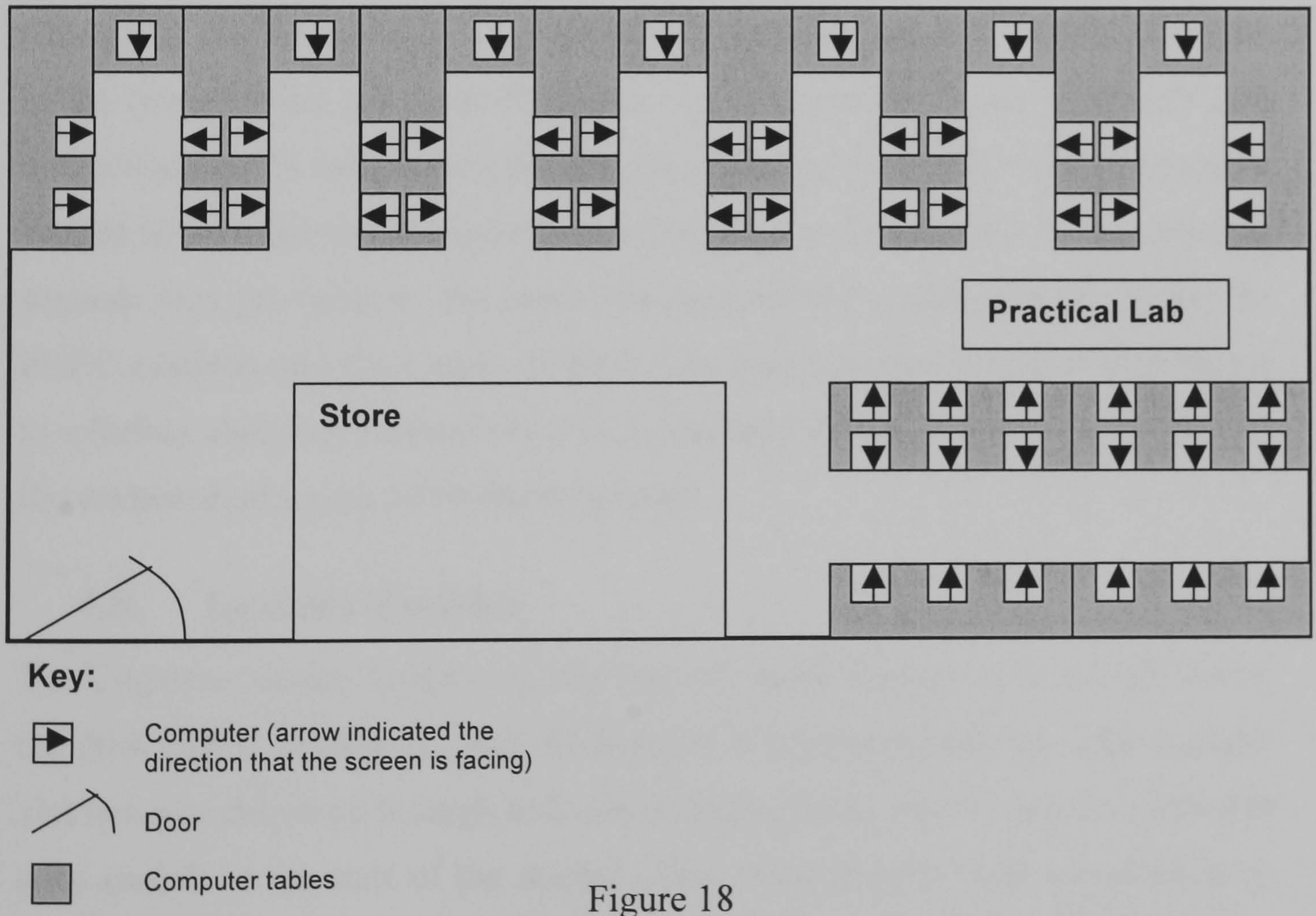


Figure 18

My observation of the students' interactions and approach to using EDEC differed considerably from those during the subsequent practical labs. During the EDEC sessions the students were generally observed working individually, with little evidence of peer to peer interaction as compared with the practical lab environment where they were often seen to cooperate within larger groups as they progressed through the programming tasks. During the EDEC lab sessions it was noted that the group of students in the small mezzanine lab tended to work in a much more cooperative manner than in the main computer cluster. This may have been due to the more intimate nature of the smaller lab environment. It may also have been due to the lecturer offering support within the main cluster and a demonstrator providing most of the support to the mezzanine cluster. thus leading to students' feeling more comfortable in asking questions of each other.

4.7. The Practical Lab Sessions

The practical lab sessions that followed EDEC were intended to use the knowledge gained during the EDEC sessions. At the start of the first lab session all students were given a workbook entitled, "Introduction to Assembly Language," (Appendix E) which outlined a number of tasks and provided support in the form of simple assembly language instructions. They worked in pairs throughout the lab sessions. It was however made clear by the lecturer at the start of the sessions that the handout should not be regarded as providing sufficient instructions on its own to successfully complete the assignment which would be handed in for assessment purposes. Further support during each of the practical sessions was provided by the same two demonstrators who assisted during the EDEC sessions and the course lecturer. The course reader was also highlighted as a further source of support however it appeared during the sessions that few of the students had a copy of the book to hand.

4.8. Learner Profiles

The Cognitive Styles Analysis (CSA) test was administered to the sample before the third EDEC session to form the basis of a learning profile for each student. The test was delivered through individual floppy disks, which were distributed to each student at the start of the session. They were given a brief introduction to the test and instructions about how it should be completed prior to beginning. The advice which accompanied the test, (not to over elaborate on the content of the test in case it affected the validity of the results) was also adhered to. At the end of the test the students were asked to return their disks, which held their results for analysis after noting down their individual results. An interpretation sheet (Appendix F) that described the test as well as providing a brief interpretation of the results was then given to all students as a means of feedback. This was supported by a brief discussion with individual students where desired. Table 31 gives a breakdown of cognitive styles for the sample.

Breakdown of Students' Cognitive Style (n=37)			
Wholist/Analytic Style	**Frequency**	**Verbaliser/Imager Style**	**Frequency**
Wholist	7	Verbaliser	11
Intermediate	9	Bimodal	9
Analytic	21	Imager	17

Table 31

The data was screened for validity through analyses of the speed index (the time taken to complete each test) and the percentage of correct answers for each dimension. According to Riding (2001), the speed index for respondents should not normally rise above a figure of 10. Since only one respondent over the two dimensions exceeded a score of 10 (10.09) as can be seen in Table 32, the results were deemed as valid against this measure.

	Wholist/Analytic Speed Index	Verbaliser/Imager Speed Index
Mean	5.81	3.03
Median	5.60	2.92
Std. Deviation	1.83	1.12
Minimum	2.72	1.16
Maximum	10.09	6.07

Table 32

Riding also indicated that if the number of correct answers was less than 70% over each of the two dimensions, the result should be regarded as being potentially problematic. Upon analysis of this measure (Table 33) it was found that no respondents fell below this threshold and therefore the results were again confirmed as being valid.

	Wholist/Analytic % Correct	Verbaliser/Imager % Correct
Mean	98.22	89.03
Median	98.00	92.00
Std. Deviation	2.20	8.48
Minimum	93	71
Maximum	100	100

Table 33

4.9. Student Perceptions

At the end of the six-week teaching block the students were asked for their perceptions of the EDEC material through the administration of a perceptions questionnaire (Appendix A). The following categories of perception were covered by the questionnaire:

1. Learnability of the EDEC interface
2. Navigability of the EDEC interface
3. Quality of the EDEC interface
4. Graphic and interactive elements
5. Overall student perceptions
6. Preparation for practical labs
7. Computers and Internet

The results of students' perceptions of the learnability of the EDEC interface (Table 34) indicated a generally positive response in terms of the instructions given and the ease of familiarity with the interface. Only 9 out of the 45 respondents expressed a problem with parts of the system. They were however less positive in their perception of the support available from the package when they became confused. Only a quarter (11 out of 44) of the sample felt that there was sufficient support. One student commented,

"The response is fixed. If one does not understand there is no further help."

Results of Learnability of EDEC Interface – Frequency of Responses (n=44 or 45)					
Learnability	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I could follow the instructions clearly.	0	1	9	15	20
I quickly became familiar with the system.	0	2	7	11	24
Parts of the system were difficult to use.	12	19	5	8	1
The instructions on screen were sufficient when needed.	0	5	15	18	7
The system helped me if I got confused.	4	13	16	8	3

Table 34

The respondents indicated no real problems with their ability to navigate satisfactorily through the EDEC modules. Table 35 demonstrates a generally high proportion of positive responses to statements concerning the navigability of the EDEC interface.

Results of Navigability of EDEC Interface - Frequency of Responses (n=45)					
Navigability	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
It was clear to me where I was in the system.	0	5	8	12	20
It was clear how to move through the system.	2	2	6	10	25
I think that the system is generally well structured.	1	2	12	11	19

Table 35

When the students were asked to give their perceptions of the quality of the EDEC interface (Table 36) the responses were generally positive towards the presentation of information, the use of language and the interface more generally. The only area of concern apparent from the results came from respondents' perceptions of their ability to retrieve the information they needed quickly from the system, with 25 responding neutral/disagree. This response may allude to the goal-orientated approach observed during their use of the package (see section 4.17.2) where many students simply wished to complete each module in as short a time as possible, with little evidence of reflection on the content and backward navigation where required.

Results of Quality of EDEC interface - Frequency of Responses (n=45 or 46)					
Quality	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I found that the information was presented consistently.	0	1	14	22	9
It was obvious how to use the icons (buttons).	0	1	3	17	25
The language was clear.	0	1	4	22	19
I could easily read from the screen.	0	1	4	17	23
The screen colour did not interfere with my reading.	0	1	5	18	21
I got what I wanted from the system quickly.	0	6	19	15	6
Overall, the system had an attractive presentation.	0	5	9	21	11
There was too much information on each page for me to remember.	11	19	11	3	2
There was too much information which I didn't need to know.	9	21	13	2	1

Table 36

Table 37 shows the results of respondents' perceptions of the graphic, animated and interactive elements. In general, these were positive towards the use of graphics in support of the learning experience. Most of the students were comfortable with the speed of the animated elements with only eight respondents agreeing that they were too fast. They did however highlight some areas of concern, particularly with regard to their inability to control the speed and starting and stopping of animations when required. There was also evidence from some of the students' comments (see Appendix L) of problems with the processing of on-screen information due to either the speed of animation or the amount of information required to be processed. A couple of the comments highlighted problems with the processing of animated media and the inability to 'chunk' the information which may have led to some of the subsequently observed problems with recall of information.

Comment 1 - *"Sometimes too much at once."*

Comment 2 - *"Sometimes moved too fast, didn't give time to read."*

One comment in particular highlighted the conflicting demands of processing textual and visual media at the same time,

Sometimes it took your mind off the text and you had to repeat it."

Evaluation of graphic, animated and interactive elements - Frequency of Responses (n=44 or 45)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I thought that the graphics were clear and helpful.	0	0	6	21	18
I thought that the interactive elements were difficult to find.	9	24	6	3	2
I found the animated elements too fast.	11	14	12	4	4
I felt that the animated elements would have been better if I could control speed and stop/start.	2	4	7	16	16
The use of images to support text was useful.	0	1	9	19	16
There was too much happening at one time with some animations.	7	12	10	10	6
The animations were too long.	7	17	10	8	3

Table 37

The students' overall perceptions of the EDEC package were generally positive. There was however a slight drop in the number of respondents who agreed that they would use EDEC again in their studies (Table 38).

This most likely indicated other resource preferences among the students as was further evidenced in their responses to the Learning Resource Questionnaire (see section 5.10).

Students' Overall Perceptions of the EDEC system - Frequency of Responses (n=46)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Overall, I liked using the system.	1	3	10	22	10
I would use this system again in my studying.	3	3	12	17	11
I would recommend the system to other students.	0	6	9	20	11

Table 38

Since the EDEC modules were intended to provide support for the three subsequent practical lab sessions, the students were asked to respond to the statement, *'the EDEC modules prepared me well for the practical lab sessions'*. Table 39 indicates that many respondents did not feel that the modules had provided sufficient support for the practical labs.

Students' Perceptions of EDEC as Preparation for Practical labs - Frequency of Responses (n=45)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
The EDEC modules prepared me well for the lab sessions.	7	10	19	6	3

Table 39

The students' perception of their role as learners in taking responsibility for their own learning was apparent in some of their comments. While EDEC was regarded as core to the learning required for the practical labs the course lecturer had encouraged the students to engage in independent learning using other resources provided in a reading list. While it was clear from the comments that the EDEC modules had provided some support for the subsequent practical labs they also provided evidence of some students' perception of EDEC as the sole provider of the knowledge required to undertake the practical assignments.

Comment 1 - *"The EDEC program was very useful, but did not prepare me for the practical lab sessions."*

Comment 2 – *"The system was quite useful in showing the basics needed for the lab sessions. Although it didn't show everything what was needed it gave a basic understanding to give a head start in the labs."*

In order to support the perceptions data relating to the EDEC package the students were asked some general questions regarding their use of computers and the Internet (Table 40). The results highlighted the increasing importance of the Internet to students' learning with 31 out of 46 respondents indicating that the Internet was useful to their learning. Eleven of these students also responded that they used the Internet mostly in relation to their coursework.

Computer and Internet perceptions - Frequency of Responses (n=44 or 46)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I like to learn using computer packages.	2	4	11	11	18
I like to play games on a computer.	6	3	9	9	19
The Internet is very useful to my learning.	4	4	7	13	18
	Less than once a month	**Around once a week**	**3 or 4 time a week**	**Most days**	**Never used one**
How often do you use a computer?	1	2	2	41	0
How often do you use the Internet?	0	2	7	37	0
	Own use	**Coursework/project research**		**Shopping**	**Other**
What do you use the Internet most for?	28	11		1	4

Table 40

4.10. Learning Resource Questionnaire

The administration of the Learning Resource Questionnaire was intended to gain an insight into the students' resource preferences (Table 41).

Usefulness of resource Frequency of Responses (n=23* or 46)					
	Useless	**Not very useful**	**Useful**	**Vital**	**Not sure**
Lectures	2	6	24	13	1
Textbook(s)	12	11	16	3	4
EDEC computer package	1	8	26	11	0
Own notes from lectures/labs	2	1	21	22	0
Borrowed notes from someone else	10	9	21	2	4
Discussions with tutor/lecturer	1	3	19	21	2
Discussions with other students	1	4	21	19	1
Other resources* (n=23)	8	4	3	4	4

Table 41

The data indicated some interesting perceptions of the usefulness of the various resources available. Most notably, the importance of face to face contact to the students was clearly evident. The interaction between students in support of their learning was widely observed during the practical lab sessions, although this was not the case during the EDEC sessions where they tended to work individually. Through discussion with a number of students during both the EDEC and practical lab sessions, the issue of support was highlighted on a number of occasions. Some students expressed a lack of confidence in the tasks covered by the labs, which led to a greater degree of self-help through peer discussion, particularly during the practical labs.

4.11. Student Perceptions and Cognitive Style

The relationship between the students' cognitive styles and their perceptions of the EDEC material and more generally Web-based learning was explored through bivariate analysis of selected data collected from the Cognitive Styles Analysis test and the perceptions questionnaire. The following hypotheses were tested in relation to students' perceptions of the EDEC package and their cognitive style.

3. Sensory (verbaliser/imager) cognitive style does not have an effect on students' perceptions of the EDEC system.

4. Organisational (wholist/analytic) cognitive style does not have an effect on students' perceptions of the EDEC system.

Due to the non-parametric nature of the data, Spearman's test was used to compare individual responses from the perceptions questionnaire with cognitive style over the two dimensions, organisational and sensory. Before the students were asked for their perceptions of EDEC they were asked if they liked to learn using computer packages in general. While Table 42 shows no discernable relationship between sensory cognitive style and the students' responses a significant relationship was observed for organisational cognitive style implying that wholist students were more likely to have a positive perception of computer-based learning packages than their analytic counterparts.

Comparison of Cognitive Style and Students' Perceptions of Learning Using Computer Packages

			I like to learn using computer packages.
Spearman's rho	Verbaliser/Imager Ratio	Correlation Coefficient	.092
		Sig. (2-tailed)	.622
		N	31
	Wholist/Analytic Ratio	Correlation Coefficient	-.442*
		Sig. (2-tailed)	.013
		N	31

*. Correlation is significant at the .05 level (2-tailed).

Table 42

When the students' perceptions of the learnability of the EDEC package was tested against cognitive style (Table 43) only one significant relationship emerged, between the students' ability to follow on-screen instructions and sensory cognitive style (corr. coeff. = 0.378, p=0.04). In general, however, the analysis identified no relationship between the students' perceptions of the learnability of EDEC and cognitive style.

Comparison of Cognitive Style and Students' Perceptions of Learnability of EDEC

			Wholist/Analytic Ratio	Verbaliser/Imager Ratio
Spearman's rho	I could follow the instructions clearly.	Correlation Coefficient	-.116	.378*
		Sig. (2-tailed)	.543	.040
		N	30	30
	I quickly became familiar with the system.	Correlation Coefficient	-.203	.272
		Sig. (2-tailed)	.290	.154
		N	29	29
	Parts of the system were difficult to use.	Correlation Coefficient	-.001	-.279
		Sig. (2-tailed)	.996	.135
		N	30	30
	The instructions on screen were sufficient when needed.	Correlation Coefficient	-.080	.020
		Sig. (2-tailed)	.676	.915
		N	30	30
	The system helped me if I got confused.	Correlation Coefficient	.295	.172
		Sig. (2-tailed)	.114	.362
		N	30	30

*. Correlation is significant at the .05 level (2-tailed).

Table 43

The analysis of students' perceptions of the navigability of EDEC and cognitive style (Table 44) again indicated no statistical relationship between perception and cognitive style with the exception of the students' perception of how clear it was to move through the package where a significant negative correlation with organisational cognitive style was observed (corr. coeff. = -4.00, p=0.028). This finding indicated that wholist students were more likely to agree with the statement than their analytic counterparts.

Comparison of Cognitive Style and Students' Perceptions of Navigability of EDEC

			Wholist/Analytic Ratio	Verbaliser/Imager Ratio
Spearman's rho	It was clear to me where I was in the system.	Correlation Coefficient	-.145	.027
		Sig. (2-tailed)	.444	.889
		N	30	30
	It was clear how to move through the system.	Correlation Coefficient	-.400*	.074
		Sig. (2-tailed)	.028	.698
		N	30	30
	I think that the system is generally well structured.	Correlation Coefficient	-.155	.189
		Sig. (2-tailed)	.412	.318
		N	30	30

*. Correlation is significant at the .05 level (2-tailed).

Table 44

The comparison of cognitive style and the students' perceptions of the quality of EDEC followed a similar pattern with little or no evidence of a relationship between perception and cognitive style (Table 45). The significant relationship observed between sensory style and students' perceptions of screen colour (corr.

coeff. = 0.401, p=0.025) was of some interest as it implied that imager students were less likely to have problems with the screen colour. It was noted however that only one student from the sample indicated that there was a problem with the screen colour.

Comparison of Cognitive Style and Students' Perceptions of the Quality of EDEC

			Wholist/Analytic Ratio	Verbaliser/Imager Ratio
Spearman's rho	I found that the information was presented consistently.	Correlation Coefficient	-.015	-.048
		Sig. (2-tailed)	.935	.799
		N	31	31
	It was obvious how to use the icons (buttons).	Correlation Coefficient	-.183	.139
		Sig. (2-tailed)	.324	.455
		N	31	31
	The language was clear.	Correlation Coefficient	.106	.083
		Sig. (2-tailed)	.569	.657
		N	31	31
	I could easily read from the screen.	Correlation Coefficient	-.185	.193
		Sig. (2-tailed)	.319	.297
		N	31	31
	The screen colour did not interfere with my reading.	Correlation Coefficient	-.005	.401*
		Sig. (2-tailed)	.980	.025
		N	31	31
	I got what I wanted from the system quickly.	Correlation Coefficient	-.234	.334
		Sig. (2-tailed)	.205	.066
		N	31	31
	Overall, the system had an attractive presentation.	Correlation Coefficient	.163	.038
		Sig. (2-tailed)	.382	.841
		N	31	31
	There was too much information on each page for me to remember.	Correlation Coefficient	.249	-.054
		Sig. (2-tailed)	.177	.773
		N	31	31
	There was too much information which I didn't need to know.	Correlation Coefficient	-.116	.006
		Sig. (2-tailed)	.535	.976
		N	31	31

*. Correlation is significant at the .05 level (2-tailed).

Table 45

The analysis of students' perceptions of the graphic, animated and interactive elements were of particular interest as it was here that any strong relationships between media and cognitive style would be explored. The analysis outlined in Table 46 showed no consistent relationship between perceptions and cognitive style, however there was a significant relationship observed between organisational cognitive style and the students' perception of the speed of animations (corr. coeff. = 0.475, p=0.007). This finding was interesting in that it indicated that analytic students were more likely to find the animations too fast than their wholist counterparts and may suggest that the analytic students had some problems with processing conceptual information from animation due to their speed. This may also be attributable to their preference for breaking information down to its constituent parts whereas wholist students would have been more likely to view animations as a whole.

Comparison of Cognitive Style and Students' Perceptions of Graphic, Animated and Interactive Elements of EDEC

			Wholist/Analytic Ratio	Verbaliser/Imager Ratio
Spearman's rho	I thought that the graphics were clear and helpful.	Correlation Coefficient	.058	.055
		Sig. (2-tailed)	.756	.769
		N	31	31
	I thought that the interactive elements were difficult to find.	Correlation Coefficient	-.014	-.126
		Sig. (2-tailed)	.942	.501
		N	31	31
	I found the animated elements too fast.	Correlation Coefficient	.475**	.027
		Sig. (2-tailed)	.007	.885
		N	31	31
	I felt that the animated elements would have been better if I could control speed and stop/start.	Correlation Coefficient	.044	-.059
		Sig. (2-tailed)	.816	.754
		N	31	31
	The use of images to support text was useful.	Correlation Coefficient	-.239	-.354
		Sig. (2-tailed)	.195	.051
		N	31	31
	There was too much happening at one time with some animations.	Correlation Coefficient	.219	-.088
		Sig. (2-tailed)	.237	.639
		N	31	31
	The animations were too long.	Correlation Coefficient	-.018	-.255
		Sig. (2-tailed)	.925	.166
		N	31	31

**. Correlation is significant at the .01 level (2-tailed).

Table 46

When the students' overall perceptions of EDEC were tested against cognitive style a similar pattern emerged with no demonstrable relationship evident over both style dimensions (Table 47).

Comparison of Cognitive Style and Students' Overall Perceptions of EDEC

			Wholist/Analytic Ratio	Verbaliser/Imager Ratio
Spearman's rho	Overall, I liked using the system.	Correlation Coefficient	-.049	.030
		Sig. (2-tailed)	.792	.875
		N	31	31
	I would use this system again in my studying.	Correlation Coefficient	-.087	-.009
		Sig. (2-tailed)	.643	.960
		N	31	31
	I would recommend the system to other students.	Correlation Coefficient	-.171	-.043
		Sig. (2-tailed)	.358	.818
		N	31	31

Table 47

Since the analysis of students' perceptions against cognitive style over both style dimensions indicated little or no relationship between perception and cognitive style both hypotheses three and four could generally be regarded as being upheld.

A further investigation of the students' perceptions of the usefulness of various resources during the six sessions was carried out using data from the Learning Resource Questionnaire (Table 48). When each resource was tested against cognitive style using Spearman's test a clear and relatively strong relationship was observed between organisational cognitive style and EDEC (corr. coeff. = -0.475, p=0.007), indicating that wholist students were much more likely to have found EDEC useful to their learning than analytic students. Significant negative correlations between organisational cognitive style and borrowed note and discussion with students also indicated a more social approach to the use of resources among wholist students. There was no evidence of any significant relationships between sensory cognitive style and the various learning resources.

Comparison of Cognitive Style and Students' Perceptions of the Usefulness of Learning Resources

			Wholist/Analytic Ratio	Verbaliser/Imager Ratio
Spearman's rho	Lectures	Correlation Coefficient	.163	-.088
		Sig. (2-tailed)	.381	.637
		N	31	31
	Textbook(s)	Correlation Coefficient	.045	-.247
		Sig. (2-tailed)	.821	.205
		N	28	28
	EDEC modules	Correlation Coefficient	-.475**	.024
		Sig. (2-tailed)	.007	.897
		N	31	31
	Own notes	Correlation Coefficient	.033	.059
		Sig. (2-tailed)	.861	.754
		N	31	31
	Borrowed notes	Correlation Coefficient	-.393*	-.024
		Sig. (2-tailed)	.038	.905
		N	28	28
	Discussion with tutor/lecturer	Correlation Coefficient	-.341	-.262
		Sig. (2-tailed)	.065	.162
		N	30	30
	Discussion with students	Correlation Coefficient	-.416*	.041
		Sig. (2-tailed)	.020	.829
		N	31	31
	Other resource	Correlation Coefficient	-.048	-.265
		Sig. (2-tailed)	.883	.405
		N	12	12

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 48

4.12. Approach to Learning

Biggs, Kember and Leung's (2001) Revised Study Process Questionnaire (R-SPQ-2F) was administered to the students in order to profile them according to their approach to learning. Tables 49 to 51 gives breakdowns of the results over the three categories tested (approach, motivation and strategy).

	Deep/Surface approach
	Number of students
Deep approach	22
Surface approach	14
Equal	2

Table 49

	Deep/Surface motivation
	Number of students
Deep motivation	21
Surface motivation	12
Equal	5

Table 50

	Deep/Surface strategies
	Number of students
Deep strategy	17
Surface strategy	16
Equal	5

Table 51

From the tables it can be seen that while 58% of students profiled as having a deep approach to learning, further analysis of the data indicated that this figure dropped to 44% for deep strategy, with a greater proportion demonstrating a surface strategy.

4.13. Student Perceptions and Approach to Learning

Based on the general hypothesis that approach to learning may have had an impact on the students' perceptions of the EDEC package and its presentation the data collected from the R-SPQ-2F was tested against students' responses to the perceptions questionnaire. This was intended to identify potential relationships between the R-SPQ-2F results and perceptions variables. The same three hypotheses that were tested during the first case study were applied to the second cohort of students in order to explore the data in a consistent manner.

These were:

8. Approach to learning (deep/surface) does not have an effect on students' perceptions of the EDEC system.

9. Learning strategy (deep/surface) does not have an effect on students' perceptions of the EDEC system.

10. Learner motivation (deep/surface) does not have an effect on students' perceptions of the EDEC system.

The analysis of data followed the same format as that for cognitive style, with the students' perceptions being tested against their responses to the R-SPQ-2F according to the categories outlined during the earlier analysis of perceptions. The sample for this part of the study typically varied from 44 to 46 students. When the students' perceptions of computer packages as learning tools was tested against the R-SPQ-2F results no discernable difference in perception was observed between the three dimensions, approach, strategy and motivation (Table 52).

Comparison of R-SPQ-2F Results and Students'Perceptions of Learning using Computer Packages

			I like to learn using computer packages.
Spearman's rho	Deep approach	Correlation Coefficient	.098
		Sig. (2-tailed)	.517
		N	46
	Surface approach	Correlation Coefficient	.053
		Sig. (2-tailed)	.727
		N	46
	Deep strategy	Correlation Coefficient	.217
		Sig. (2-tailed)	.147
		N	46
	Surface strategy	Correlation Coefficient	.090
		Sig. (2-tailed)	.552
		N	46
	Deep motive	Correlation Coefficient	.001
		Sig. (2-tailed)	.992
		N	46
	Surface motive	Correlation Coefficient	-.049
		Sig. (2-tailed)	.748
		N	46

Table 52

The analysis for learnability of EDEC did however demonstrate a number of significant results between the surface dimension and variables relating to learnability (Table 53). Although the correlation coefficients did not indicate that the significant relationships were particularly strong the results generally indicated that students with a strong surface tendency were more likely to have a negative perception of the learnability of EDEC than their deep counterparts.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Learnability of EDEC

			I could follow the instructions clearly.	I quickly became familiar with the system.	Parts of the system were difficult to use.	The instructions on screen were sufficient when needed.	The system helped me if I got confused.
Spearman's rho	Deep approach	Correlation Coefficient	-.090	-.108	.056	.117	.054
		Sig. (2-tailed)	.558	.485	.716	.443	.728
		N	45	44	45	45	44
	Surface approach	Correlation Coefficient	-.180	-.156	.252	-.097	-.331*
		Sig. (2-tailed)	.238	.311	.095	.527	.028
		N	45	44	45	45	44
	Deep strategy	Correlation Coefficient	-.003	.003	.088	.135	.170
		Sig. (2-tailed)	.986	.983	.563	.377	.269
		N	45	44	45	45	44
	Surface strategy	Correlation Coefficient	-.252	-.085	.378*	-.014	-.204
		Sig. (2-tailed)	.094	.584	.011	.925	.183
		N	45	44	45	45	44
	Deep motive	Correlation Coefficient	-.120	-.199	.033	.074	-.041
		Sig. (2-tailed)	.433	.196	.832	.629	.790
		N	45	44	45	45	44
	Surface motive	Correlation Coefficient	-.138	-.146	.192	-.114	-.353*
		Sig. (2-tailed)	.364	.343	.207	.456	.019
		N	45	44	45	45	44

*. Correlation is significant at the .05 level (2-tailed).

Table 53

When the students' perceptions of the navigability of EDEC were compared with their responses to the R-SPQ-2F there was no evidence of any relationship between variables (Table 54), although the generally negative nature of the results across the surface dimension indicated a more negative perception from students who tended towards the surface end of the scale.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Navigability of EDEC

			It was clear to me where I was in the system.	It was clear how to move through the system.	I think that the system is generally well structured.
Spearman's rho	Deep approach	Correlation Coefficient	.201	.121	.182
		Sig. (2-tailed)	.186	.430	.231
		N	45	45	45
	Surface approach	Correlation Coefficient	-.015	.007	-.019
		Sig. (2-tailed)	.924	.962	.902
		N	45	45	45
	Deep strategy	Correlation Coefficient	.221	.086	.228
		Sig. (2-tailed)	.144	.573	.131
		N	45	45	45
	Surface strategy	Correlation Coefficient	-.022	-.024	-.088
		Sig. (2-tailed)	.887	.874	.567
		N	45	45	45
	Deep motive	Correlation Coefficient	.157	.164	.129
		Sig. (2-tailed)	.303	.281	.397
		N	45	45	45
	Surface motive	Correlation Coefficient	.029	-.027	.022
		Sig. (2-tailed)	.848	.858	.884
		N	45	45	45

Table 54

While there was little evidence of a strong relationship between the students' perception of the quality of EDEC and R-SPQ-2F results, the analysis once again indicated a less positive perception from students with a surface tendency (Table 55). In particular, the significant correlation (corr. coeff. = 0.389, p=0.007) between surface strategy and responses to the statement *'there was too much information which I didn't need to know'* indicated a goal-orientated approach by these students and may support the observational findings where some students were observed to skim over animated material which required more rigorous processing.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Quality of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I found that the information was presented consistently.	Correlation Coefficient	-.024	-.251	-.056	-.266	-.019	-.148
		Sig. (2-tailed)	.877	.092	.713	.074	.901	.328
		N	46	46	46	46	46	46
	It was obvious how to use the icons (buttons).	Correlation Coefficient	.003	.030	.040	-.076	-.053	.036
		Sig. (2-tailed)	.985	.841	.794	.617	.725	.812
		N	46	46	46	46	46	46
	The language was clear.	Correlation Coefficient	.187	-.084	.230	-.112	.099	-.077
		Sig. (2-tailed)	.213	.578	.125	.458	.512	.612
		N	46	46	46	46	46	46
	I could easily read from the screen.	Correlation Coefficient	.176	.022	.265	.094	.103	-.006
		Sig. (2-tailed)	.248	.886	.078	.538	.501	.968
		N	45	45	45	45	45	45
	The screen colour did not interfere with my reading.	Correlation Coefficient	-.013	-.153	-.013	-.111	-.002	-.130
		Sig. (2-tailed)	.932	.316	.932	.469	.989	.393
		N	45	45	45	45	45	45
	I got what I wanted from the system quickly.	Correlation Coefficient	-.072	-.185	-.001	-.142	-.127	-.144
		Sig. (2-tailed)	.634	.218	.996	.347	.400	.341
		N	46	46	46	46	46	46
	Overall, the system had an attractive presentation.	Correlation Coefficient	.328*	-.233	.396**	-.226	.233	-.182
		Sig. (2-tailed)	.026	.119	.006	.131	.120	.226
		N	46	46	46	46	46	46
	There was too much information on each page for me to remember.	Correlation Coefficient	-.007	.160	-.031	.053	.014	.125
		Sig. (2-tailed)	.965	.287	.839	.727	.924	.408
		N	46	46	46	46	46	46
	There was too much information which I didn't need to know.	Correlation Coefficient	-.042	.257	-.011	.389**	-.074	.197
		Sig. (2-tailed)	.782	.085	.940	.007	.627	.189
		N	46	46	46	46	46	46

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Table 55

The results of the students' perceptions of graphic, animated and interactive elements against approach to learning indicated a number of relationships between surface tendency and problems with information processing (Table 56). The significant relationships that were observed across the three surface scales (approach, strategy and motivation), particularly in relation to the speed and quantity of information required to be processed through animation certainly implied that surface learners had more difficulty with these than their deep counterparts. It could be speculated that this was due to the additional processing requirements (sequential and parallel) of animated media when compared with still media thus requiring a more rigorous approach to processing for effective conceptual understanding.

Comparison of R-SPQ-2F Results and Students' Perceptions of Graphic, Animated and Interactive Elements of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I thought that the graphics were clear and helpful.	Correlation Coefficient	.003	-.187	.183	-.216	-.137	-.125
		Sig. (2-tailed)	.985	.218	.228	.153	.370	412
		N	45	45	45	45	45	45
	I thought that the interactive elements were difficult to find.	Correlation Coefficient	.087	.416**	.009	.430**	.120	341*
		Sig. (2-tailed)	.576	.005	.954	.004	.436	023
		N	44	44	44	44	44	44
	I found the animated elements too fast.	Correlation Coefficient	-.006	.395**	.021	.308*	-.016	.453**
		Sig. (2-tailed)	.968	.007	.892	.040	.919	.002
		N	45	45	45	45	45	45
	I felt that the animated elements would have been better if I could control speed and stop/start.	Correlation Coefficient	-.032	.367*	-.003	.366*	-.080	.321*
		Sig. (2-tailed)	.832	.013	.984	.013	.603	.031
		N	45	45	45	45	45	45
	The use of images to support text was useful.	Correlation Coefficient	.179	-.288	.159	-.270	.161	-.237
		Sig. (2-tailed)	.238	.055	.298	.073	.291	.117
		N	45	45	45	45	45	45
	There was too much happening at one time with some animations.	Correlation Coefficient	.012	.380**	-.034	.317*	.029	.363*
		Sig. (2-tailed)	.935	.010	.826	.034	.850	.014
		N	45	45	45	45	45	45
	The animations were too long.	Correlation Coefficient	.136	.227	.096	.149	.146	.260
		Sig. (2-tailed)	.372	.134	.529	.328	.337	.084
		N	45	45	45	45	45	45

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Table 56

When the results of the R-SPQ-2F were compared with the students' overall perceptions of EDEC (Table 57) there was little evidence of a strong relationship between either of the deep and surface dimensions and perception. There was however a significant positive correlation observed between deep strategy and the statement, *'overall, I liked using the system'* (corr. coeff. = 0.317, p=0.032). Once again the general tendency was for students who tended towards the deep end of the spectrum to have a more positive overall perception of EDEC than those with a surface tendency.

Comparison of R-SPQ-2F Results and Students' Overall Perceptions of EDEC

			Overall, I liked using the system.	I would use this system again in my studying.	I would recommend the system to other students.
Spearman's rho	Deep approach	Correlation Coefficient	.181	-.084	.174
		Sig. (2-tailed)	.228	.577	.246
		N	46	46	46
	Surface approach	Correlation Coefficient	.006	.005	-.055
		Sig. (2-tailed)	.967	.975	.717
		N	46	46	46
	Deep strategy	Correlation Coefficient	.317*	.014	.270
		Sig. (2-tailed)	.032	.927	.069
		N	46	46	46
	Surface strategy	Correlation Coefficient	-.076	-.051	-.109
		Sig. (2-tailed)	.613	.737	.469
		N	46	46	46
	Deep motive	Correlation Coefficient	.043	-.129	.101
		Sig. (2-tailed)	.775	.395	.503
		N	46	46	46
	Surface motive	Correlation Coefficient	.006	.010	-.034
		Sig. (2-tailed)	.971	.947	.820
		N	46	46	46

*. Correlation is significant at the .05 level (2-tailed).

Table 57

Finally, the analysis of the students' perceptions of EDEC as preparation for the subsequent practical labs generally indicated that those students who scored highly on the deep scales were more positive in their responses than those who score highly in the surface scales (Table 58). In particular, a significant relationship was observed between the deep strategy scale and the students' responses (corr. coeff. = 0.337, p=0.024). This finding corresponded with the students' overall perception of EDEC outlined in Table 57 and conformed to the general trend relating deeper learners with a more positive perception of the package.

Comparison of R-SPQ-2F Results and the Students' Perceptions of EDEC as Preparation for the Practical Labs

			The EDEC modules prepared me well for the lab sessions.
Spearman's rho	Deep approach	Correlation Coefficient	.223
		Sig. (2-tailed)	.142
		N	45
	Surface approach	Correlation Coefficient	-.115
		Sig. (2-tailed)	.451
		N	45
	Deep strategy	Correlation Coefficient	.337*
		Sig. (2-tailed)	.024
		N	45
	Surface strategy	Correlation Coefficient	-.054
		Sig. (2-tailed)	.722
		N	45
	Deep motive	Correlation Coefficient	.082
		Sig. (2-tailed)	.593
		N	45
	Surface motive	Correlation Coefficient	-.141
		Sig. (2-tailed)	.354
		N	45

*. Correlation is significant at the 0.05 level (2-tailed).

Table 58

A comparison of the students' perceptions of the usefulness of various learning resources and their R-SPQ-2F results (Table 59) indicated a more self-reliant approach from students' with a deep tendency as evidenced in the significant correlations between deep approach and strategy and the usefulness of the student's own notes. Perhaps not surprisingly, the analyses generally indicated that students with a deep tendency typically employed a more diverse approach to resource use than those with a surface tendency.

Comparison of R-SPQ-2F Results and Students' Perceptions of the Usefulness of Learning Resources

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	Lectures	Correlation Coefficient	.180	.058	.208	.050	.155	-.037
		Sig. (2-tailed)	.238	.704	.171	.742	.309	.809
		N	45	45	45	45	45	45
	Textbook(s)	Correlation Coefficient	.323*	.118	.361*	.127	.269	.064
		Sig. (2-tailed)	.037	.456	.019	.423	.085	.686
		N	42	42	42	42	42	42
	EDEC modules	Correlation Coefficient	.022	.013	.111	-.095	-.073	.006
		Sig. (2-tailed)	.886	.932	.464	.528	.631	.969
		N	46	46	46	46	46	46
	Own notes	Correlation Coefficient	.325*	-.037	.418**	-.001	.208	-.143
		Sig. (2-tailed)	.027	.805	.004	.993	.166	.342
		N	46	46	46	46	46	46
	Borrowed notes	Correlation Coefficient	-.131	.381*	-.261	.370*	-.009	.336*
		Sig. (2-tailed)	.408	.013	.095	.016	.956	.030
		N	42	42	42	42	42	42
	Discussion with tutor/lecturer	Correlation Coefficient	-.037	.083	.045	.178	-.100	.046
		Sig. (2-tailed)	.810	.593	.773	.247	.517	.769
		N	44	44	44	44	44	44
	Discussion with students	Correlation Coefficient	-.196	.004	-.108	.075	-.221	-.108
		Sig. (2-tailed)	.196	.980	.482	.623	.145	.479
		N	45	45	45	45	45	45
	Other resource	Correlation Coefficient	.592**	.244	.562*	.190	.459*	.249
		Sig. (2-tailed)	.008	.314	.012	.437	.048	.304
		N	19	19	19	19	19	19

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Table 59

In general, the reults indicated that students who tended towards the deeper end of the spectrum were more positively disposed towards the EDEC package than their surface counterparts. While the results were not conclusive they did demonstrate a degree of significance for the sample which challenged the related hypotheses (8 to 10) outlined. This was particularly evident in responses to statements relating to information processing where a consistent relationship was observed between surface tendency and the students perceptions of animated elements within the package.

4.14. Pre/Post-Test Quizzes

In order to ascertain the degree of learning that the EDEC modules facilitated, two pre-test/post-test quizzes were carried out with the sample before and after two of the EDEC modules. Each of these took the form of ten multiple choice questions which were derived from the content of each module. The two quizzes were titled, 'Number Systems' and 'Introduction to Computer Systems' respectively (see Appendices G and H). On each occasion. the content of the quiz was reviewed and approved by the course lecturer prior to administration. Care was taken to design questions based on the media and delivery methods that were used during each module and in particular, with a view to evaluating the animated and interactive elements of the system. Tables 60 and 61 give a breakdown of the quiz questions and the method of presentation of content for each of the EDEC modules.

Breakdown of Media – Pre/Post Test 1 – Number Systems			
Question No.	**Type of Content**	**Duration (if applicable)**	**Notes**
Q.1	Interactive		Drag and drop question
Q.2	Text		
Q.3	Text		
Q.4	Animation	21.5 seconds	Continuous animation
Q.5	Animation	20.5 seconds	Continuous animation
Q.6	Animation	20.5 seconds	Continuous animation
Q.7	Interactive		Drag and drop question
Q.8	Animation	37 seconds	Continuous animation
Q.9	Animation	14.5 seconds	Continuous animation
Q.10	Animation	35 seconds	Continuous animation

Table 60

Breakdown of Media – Pre/Post Test 2 – Introduction to Computer Systems			
Question No.	**Type of Content**	**Duration (if applicable)**	**Notes**
Q.1	Static image/text		
Q.2	Text		
Q.3	Static image/text		
Q.4	Text		
Q.5	Text		
Q.6	Animation	14 seconds	Continuous animation
Q.7	Static image		
Q.8	Interactive	37 seconds	Series of push buttons
Q.9	Text/animation	2 seconds	Continuous animation
Q.10	Animation	14 seconds	Continuous animation

Table 61

The first quiz included a number of questions relating to the binary number system and it was therefore assumed that some of the students would have had some prior knowledge of these questions. Tables 62 and 63 show the percentages of number of correct answers pre and post-test 1.

Number of correct answers in Pre-test 1

Number of correct answers	Valid Percent
2	2.0
4	2.0
5	16.3
6	12.2
7	10.2
8	24.5
9	26.5
10	6.1

Table 62

Number of correct answers in Post-test 1

Number of correct answers	Valid Percent
7	4.1
8	2.0
9	28.6
10	65.3

Table 63

While the quiz results showed a high level of correct answers both pre and post-test, there was clear evidence that the range of results had dropped considerably in the post-test when compared with the pre-test. The mean number of correct answers also increased in the post-test as indicated in Table 64.

Analysis of Pre/Post-test 1

		Number of correct answers in Pre-test 1	Number of correct answers in Post-test 1
N	Valid	49	49
	Missing	0	0
Mean		7.35	9.55
Std. Deviation		1.81	.74
Range		8	3

Table 64

When pre and post-test results were compared the number of questions answered correctly by students during the first quiz showed a positive differential for all but five respondents (Table 65). The five students who achieved no difference between their pre and post-test scores all achieved either nine or ten correct answers for both quizzes.

Difference in Number of Correct Answers for Pre/ Post-test Quiz 1

Difference	Number of Students	Valid Percent
0	5	10.2
1	16	32.7
2	9	18.4
3	7	14.3
4	6	12.2
5	3	6.1
6	1	2.0
7	1	2.0
9	1	2.0
Total	49	100.0

Table 65

When each quiz question was analysed separately, an equal or improved overall performance was observed for all of the questions (Table 66). This was most marked in the latter questions, which were less likely to have covered topics where prior knowledge may have been a factor.

Difference in Performance by Question for Quiz 1 (n=49)

	incorrect	correct	don't know
Pre Q1		98.0%	2.0%
Post Q1		100.0%	
Pre Q2		100.0%	
Post Q2		100.0%	
Pre Q3	12.2%	81.6%	6.1%
Post Q3		100.0%	
Pre Q4	4.1%	85.7%	10.2%
Post Q4		100.0%	
Pre Q5	2.0%	95.9%	2.0%
Post Q5		100.0%	
Pre Q6	6.1%	77.6%	16.3%
Post Q6	4.1%	95.9%	
Pre Q7	8.2%	75.5%	16.3%
Post Q7	2.0%	98.0%	
Pre Q8	14.3%	18.4%	67.3%
Post Q8	20.4%	79.6%	
Pre Q9	40.8%	36.7%	22.4%
Post Q9	10.2%	89.8%	
Pre Q10	12.2%	65.3%	22.4%
Post Q10	8.2%	91.8%	

Table 66

The second quiz was administered to the same sample of students as the first, although the sample size was reduced due to a drop in attendance. Percentage values for number of correct answers during each of the tests are given in Tables 67 and 68.

Number of correct answers in Pre-test 2

Number of correct answers	Valid Percent
2	2.9
4	20.6
5	11.8
6	29.4
7	14.7
8	17.6
9	2.9

Table 67

Number of correct answers in Post-test2

Number of correct answers	Valid Percent
3	2.9
6	2.9
7	5.9
8	23.5
9	29.4
10	35.3

Table 68

The generally positive differential seen in pre/post-test 1 was repeated for the second quiz (Table 69), with an increase in performance achieved in all but three cases. In particular, the two anomalous results where students achieved a lower number of correct answers post-test than their pre-test result may have indicated a degree of guessing in the case of one student who dropped from nine to eight correct answers and more likely a lack of motivation on the part of the student whose performance dropped from six to three correct answers.

Difference in Number of Correct Answers for Pre/ Post-test Quiz 2

Difference	Frequency	Valid Percent
-3	1	2.9
-1	1	2.9
0	1	2.9
1	3	8.8
2	8	23.5
3	8	23.5
4	6	17.6
5	4	11.8
6	2	5.9
Total	34	100.0

Table 69

Table 70 shows that while the range of results did not vary, the mean value for correct answers increased due to the EDEC material. The difference in range of results obtained from quizzes 1 and 2 could be attributed to the fact that quiz 1 was more likely to have contained content that had been covered previously by some students.

Analysis of Pre/Post test 2

		Number of correct answers in Pre-test 2	Number of correct answers in Post-test 2
N	Valid	34	34
	Missing	15	15
Mean		5.94	8.74
Std. Deviation		1.61	1.46
Range		7	7

Table 70

The analysis of quiz 2 by question indicated an increase in student performance in the post-test, which could be attributed to the EDEC package (Table 71). This was particularly apparent in questions 7 to 10 where a considerable increase in the percentage of the sample achieving a correct answer was observed.

Difference in Performance by Question for Quiz 1 (n=34)

	incorrect	correct	don't know
Pre 2 Q1	5.9%	94.1%	
Post 2 Q1		100.0%	
Pre 2 Q2	44.1%	20.6%	35.3%
Post 2 Q2	47.1%	50.0%	2.9%
Pre 2 Q3	14.7%	76.5%	8.8%
Post 2 Q3		100.0%	
Pre 2 Q4	11.8%	88.2%	
Post 2 Q4	5.9%	94.1%	
Pre 2 Q5	8.8%	88.2%	2.9%
Post 2 Q5	8.8%	91.2%	
Pre 2 Q6	17.6%	76.5%	5.9%
Post 2 Q6	5.9%	91.2%	2.9%
Pre 2 Q7	44.1%	20.6%	35.3%
Post 2 Q7	2.9%	97.1%	
Pre 2 Q8	26.5%	58.8%	14.7%
Post 2 Q8	17.6%	82.4%	
Pre 2 Q9	32.4%	52.9%	14.7%
Post 2 Q9		100.0%	
Pre 2 Q10	55.9%	17.6%	26.5%
Post 2 Q10	32.4%	67.6%	

Table 71

4.15. Pre/Post-Test Performance and Cognitive Style

Since it was hypothesised that cognitive style may affect student performance using the EDEC package the following hypotheses were developed around the two cognitive styles dimensions covered by the Cognitive Styles Analysis test:

1. Sensory cognitive style (verbaliser/imager) does not have an affect on students' performance in pre-test/post-test situations using the EDEC package.

2. Organisational cognitive style (wholist/analytic) does not have an affect on students' performance in pre-test/post-test situations using the EDEC package.

Due to the parametric nature of the data, Pearson's test for bivariate analysis was used to test each hypothesis. The results shown in Tables 72 and 73 generally indicated that cognitive predisposition over both the style dimensions (organisational and sensory) did not have a significant impact on students' performance during both quizzes. The only exception to this observation came in the analysis of verbaliser/imager ratio and number of correct answers during post-test quiz 2 (corr. coef. = -0.396, p=0.045). Somewhat unexpectedly, the significant negative correlation indicated that verbaliser students had performed significantly better during post-test quiz 2 than imagers. This was also the case for differentials scores over the second quiz (corr. coeff. = -0.384. p=0.053). Closer inspection of the dataset through the use of scatterplots showed one particularly anomalous result where a student achieved a differential score of -3 over pre/post-test quiz 2 (i.e. three fewer correct answers during the post-test than achieved during the pre-test). Although there was no obvious reason for this result it had the effect of skewing the results for both the number of correct answers to the post-test and the differential score. When this student was removed from the analysis, both results were non-significant (corr. coeff. = 0.320, p=0.119 and corr. coeff. = 0.007, p=0.972 respectively).

Comparison of Cognitive Style and Student Performance in Pre/Post-Test Quiz 1

		Number of correct answers in Pre-test	Number of correct answers in Post-test	Quiz 1 Differential
Wholist/Analytic Ratio	Pearson Correlation	.114	-.043	-.173
	Sig. (2-tailed)	.500	.801	.306
	N	37	37	37
Verbaliser/Imager Ratio	Pearson Correlation	.145	.078	-.046
	Sig. (2-tailed)	.390	.647	.787
	N	37	37	37

Table 72

Comparison of Cognitive Style and Student Performance in Pre/Post-Test Quiz 2

		Number of correct answers in Pre-Test	Number of correct answers in Post-Test	Quiz 2 Differential
Wholist/Analyst Ratio	Pearson Correlation	-.037	-.198	-.115
	Sig. (2-tailed)	.859	.331	.575
	N	26	26	26
Verbal/Imagery Ratio	Pearson Correlation	.103	-.396*	-.384
	Sig. (2-tailed)	.616	.045	.053
	N	26	26	26

*. Correlation is significant at the 0.05 level (2-tailed).

Table 73

The results of the analysis generally indicated that cognitive style over the two dimensions did not have an effect on the students' performance during each of the pre/post-test quizzes and to this extent the hypotheses under test were upheld in each case.

4.16. Pre/Post-Test Performance and Learning Approach

Since the analysis of perceptions against the R-SPQ-2F results indicated a partial relationship between deep tendency and perceptions of the EDEC package, it was interesting to consider whether deep or surface approach had any impact on the students' performance during the two pre/post-test quizzes. The data collected from both the Revised Study Process Questionnaire (R-SPQ) and the pre/post test quizzes were analysed in order to test the following hypotheses:

5. Deep/surface approach to learning does not have an effect on the learner's performance in pre-test/post-test situations using Web-based media (EDEC).
6. Deep/surface learning strategy does not have an effect on the learner's performance in pre-test/post-test situations using Web-based media (EDEC).
7. Deep/surface motivation does not have an effect on the learner's performance in pre-test/post-test situations using Web-based media (EDEC).

The analysis of results for pre/post test performance and approach to learning was considered in terms of students' actual scores from the pre-post/test quizzes as well as their performance differential. To this end, bivariate analyses of each of the variables generated from the Revised Study Process Questionnaire (R-SPQ) were carried out against pre/post-test results. Tables 74 and 75 indicated that there was no significant relationship between approach to learning and pre/post-test performance over the two quizzes.

Comparison of Results from R-SPQ-2F and Student Performance in Pre/Post-Test Quiz 1

		Number of correct answers in Pre-test	Number of correct answers in Post-test	Test 1 Differential
Deep approach	Pearson Correlation	-.083	-.029	-.058
	Sig. (2-tailed)	.619	.862	.730
	N	38	38	38
Surface approach	Pearson Correlation	-.009	.113	-.082
	Sig. (2-tailed)	.958	.498	.625
	N	38	38	38
Deep strategy	Pearson Correlation	-.096	.023	-.046
	Sig. (2-tailed)	.565	.891	.782
	N	38	38	38
Surface strategy	Pearson Correlation	.015	.040	-.110
	Sig. (2-tailed)	.928	.809	.511
	N	38	38	38
Deep motive	Pearson Correlation	-.060	-.071	-.060
	Sig. (2-tailed)	.719	.674	.721
	N	38	38	38
Surface motive	Pearson Correlation	-.029	.166	-.049
	Sig. (2-tailed)	.862	.320	.771
	N	38	38	38

Table 74

Comparison of Results from R-SPQ-2F and Student Performance in Pre/Post-Test Quiz 2

		Number of correct answers in Pre-test	Number of correct answers in Post-test	Test 2 Differential
Deep approach	Pearson Correlation	-.066	-.169	-.056
	Sig. (2-tailed)	.734	.380	.775
	N	29	29	29
Surface approach	Pearson Correlation	-.204	-.015	.207
	Sig. (2-tailed)	.289	.939	.280
	N	29	29	29
Deep strategy	Pearson Correlation	-.157	-.116	.082
	Sig. (2-tailed)	.416	.549	.674
	N	29	29	29
Surface strategy	Pearson Correlation	-.265	-.039	.255
	Sig. (2-tailed)	.164	.839	.182
	N	29	29	29
Deep motive	Pearson Correlation	.031	-.187	-.173
	Sig. (2-tailed)	.872	.332	.369
	N	29	29	29
Surface motive	Pearson Correlation	-.125	.009	.140
	Sig. (2-tailed)	.518	.965	.468
	N	29	29	29

Table 75

Although the earlier analysis of data indicated that surface learners had a more negative perception of the EDEC package, particularly relating to the use of media, this had no bearing on their performance before and after the intervention. The hypotheses under test were therefore upheld in each case.

4.17. Observation of the EDEC and Practical Lab Sessions

Observation notes were taken during each of the six lab sessions (see Appendix I). These included a combination of purely observational data and responses to questioning of students, demonstrators and the lecturer during each session. While the sessions were timetabled to last for three hours, notes were taken for the period of time which students were present, which was often less than the three hours. I was present for the duration of each session. All notes were taken manually and time-stamped as the sessions progressed.

A number of observations were common over the three weeks that the students used the EDEC package. While the pre/post-test quiz results had indicated a degree of learning derived from EDEC, it was observed that the students' generally took a rather goal-orientated approach to each of the three EDEC modules in terms of time spent on the modules and their approach to information processing.

4.17.1. Observation of Time Spent on the EDEC Modules

Although the students' were expected to spend around 180 minutes on each module, no session lasted beyond 90 minutes with the average time spent on the modules diminishing over the three weeks from between 60 to 90 minutes to between 40 to 60 minutes. During the second and third sessions a number of students, estimated to be around 10% of the class were observed to have left the lab within 20 to 25 minutes of the session starting.

There was a degree of peer pressure apparent in the students' completion of the modules, with an observable 'tipping point' reached once around 50% of students had finished and left the lab. This was further evidenced in the different time spent on the modules between the two separate computer clusters, with the students in the smaller cluster typically spending longer on them than those within the larger one. It was noted that this was in part due to the more collaborative approach taken in the smaller lab to the modules, where a greater degree of student interaction was evident.

4.17.2. Observation of Students' Approach to using of EDEC

During the observation of students' use of the EDEC package I concentrated on their approach to the user interface, information processing and their motivation towards the package over the three weeks of its use. The results highlighted a degree of inconsistency between the students' responses to questioning during their use of the package and my own observations. While this could be attributed to a 'Hawthorne effect', it also indicated a goal-orientated approach to the package.

The students' approach to processing media, and in particular animated media, highlighted the typically surface and goal-orientated approach taken by many. On a number of occasions individual students were observed to initiate an animation before turning to have a conversation with another student or taking notes from another part of the screen as the animation progressed. Others were observed moving on to the next screen during an animation. During one very obvious incidence of a student starting an animation before turning to have a conversation with another student, I asked him immediately afterwards how useful the animation had been to him. He replied that he thought that it had really helped to 'break down' the problem, even though he hadn't in fact reviewed the animation at all. He appeared to be aware of the purpose and benefits of the animated elements, while having little motivation to process them effectively.

Although the animations appeared to stimulate the taking of notes by some students, few were observed to have initiated multiple reviews of animated media as expected, in order to facilitate appropriate processing. This often resulted in much of the information processing taking place from the final static image at the end of the animation. While this approach did not completely prohibit the students from learning the concepts under demonstration, it did impair their ability to understand their derivation, as demonstrated through the animated examples. This became apparent during the pre-EDEC lecture in the third week where there was a general lack of response to the lecturer's questions on the content of the previous week's module. There was evidence that many of the students struggled with recall beyond surface facts relating to the concepts covered. The following excerpt from the observation log completed during the third session highlights this.

- *A general lack of responses to lecturer questions on last week's module observed. There was a real sense of a 'lack of understanding' apparent. There was some degree of surface learning evident, particularly where information processing was required.*
- *Observed definite anecdotal links between processing of animated elements and retention of information under lecturer questioning of students. This may be linked to animation timing and the fact that students generally only review animations once.*
- *Lack of responses to lecturer questions may be linked to observed tendency for many students to 'skim' previous modules during sessions.*

When a number of students were asked if a single review of the animated elements was sufficient to process their content the general response was that a single review was sufficient. They also generally expressed no problems with the processing of animated material, although some students indicated that they were sometimes too fast to allow effective processing. One student in particular highlighted his inability to process information from some animations due to their length and speed.

"Sometimes moved too fast, didn't give time to read."

By the third session it was clear that the students had become proficient at locating interactive content and there was a tendency for some to simply interact with these in a surface manner without prior processing of any introductory text. There were also instances of students becoming confused by the colour of on-screen text. This was particularly the case with blue text, where a number of students assumed that blue text indicated an interactive element. It was assumed that this was due to their association of blue text with hyperlinks as is conventional with hypermedia.

While there was clear evidence of learning taking place and of the students taking more effective notes in preparation for on-screen questions by the third session, there was also more observable off-task activity within the lab. This typically took the form of general Web browsing or e-mail activity. On no occasion was this activity observed to have been related to the current EDEC topic or task.

There was some evidence of a '*dualistic*' approach, as defined by Perry (1970), within some of the students' comments. The two comments that follow highlighted the lack of confidence exhibited by some students in taking responsibility for their own learning at this stage in their degree programme (first year).

Comment 1 – *"The modules were good except one or two more could have made things easier."*

Comment 2 – *"Perhaps an assembly language lecture as well would help."*

4.17.3. Observation of Student Note-taking and use of EDEC Workbooks

The students were strongly encouraged by the course lecturer to take notes as they progressed through each of the EDEC modules as these would support them during the subsequent practical lab sessions. During the first session the students were asked to take their own notes while for each of the following two sessions they were issued with a workbook which was intended to accompany the module and support note taking.

There was little evidence of note-taking at the start of the first session. Subsequent note-taking was observed to lack structure and typically acted as support for calculation during screens, thus offering little support during the practical labs. The issuing of workbooks before the second and third EDEC sessions (see Appendices K and L) instigated a marked increase in student note-taking and supported the learning process through the provision of both context and structure to their note-taking. Some students were also observed using the workbooks to aid recall during on-screen questions.

4.17.4. Observation of Post-EDEC Practical Lab Sessions

After the three weekly EDEC sessions the students were expected to use the knowledge gained through the EDEC modules to complete a number of practical programming tasks using assembly language. They were observed during these sessions to gain an insight into how well the EDEC modules had prepared them for the tasks as well as to observe their approach to the practical tasks in comparison to EDEC. Each lab was intended to last for three hours and the students were supported during each session by two postgraduate demonstrators and the course lecturer. There was an immediately discernable shift in the students' approach to collaboration within the practical lab environment. Although they were expected to work in groups of two during each of the labs due to the number of computers available, it was clear that the students were interacting both within and across groups. This progressed over the three sessions to a point where the students felt comfortable moving around the lab giving and getting support as and when required, independent of the support offered by the two demonstrators and the lecturer.

Although the students had their notes, taken during the EDEC sessions available to them during the practical sessions, there was little observational evidence of these being used in support of the tasks that they had to complete. When the EDEC material was discussed with a number of students during the first practical session they highlighted their lack of note-taking during EDEC as a problem. The class were split on the degree to which the EDEC modules had prepared them for the practical labs. There was a general view expressed that while the EDEC sessions had offered some support for the practical labs, it was not specific enough to support the tasks that were to be completed.

The observation and questioning of students during the practical labs indicated that they had typically retained some conceptual knowledge from the EDEC sessions, typically in the form of keywords or topics which provided limited support. More than one student indicated that the EDEC material had provided useful 'prompts' during the practical labs although they didn't provide enough detail to support the tasks themselves. I discussed this observation with one of the demonstrators at the end of the first session and he confirmed that most of the student questions he had dealt with demonstrated a lack of information retention from EDEC. There was also evidence of a lack of retention in the students' response to a question from the lecturer during the first practical session. The question related specifically to a topic covered by one of the EDEC modules. While the responses from the students indicated a familiarity with the concept there was little or no evidence of understanding of its underlying principles. The same observation was made during the second practical lab where the students struggled to answer questions that were process related (covered by animation) and based on topics covered by EDEC.

A number of students expressed a lack of confidence in the tasks covered during the second practical session. When one group were asked if the EDEC material had been their only theoretical support for the labs, they responded, *'yeah, unfortunately'*. When another group were asked if they felt that EDEC had prepared them for the practical labs they indicated that the modules had provided a useful overview in the concepts covered, although they had not prepared them for the labs. When the same group were asked about their approach to the tasks covered by the practical lab, they indicated that their approach was *'trial and error'*.

By the final session, the students were observably more confident in the problem solving tasks to be completed, with a high degree of motivation towards the tasks. Discussion with the two demonstrators during the session indicated that the students' support requirements were more focused at this stage with greater use of prior knowledge gained through previous sessions. By the third week there were no observable instances of students using notes taken during the EDEC sessions.

4.18. Discussion

It was my intention during this case study to utilise a number of complementary tools and methodologies to gain an understanding of the dynamic and structural issues involved in learning using the EDEC package as preparation for the practical labs that were intended to put the knowledge gained into practice. The findings suggested that neither cognitive style nor approach to learning had any observable bearing on the students' performance over the two pre/post-test quizzes. There was however some evidence to suggest that students who profiled as having a deep learning tendency were more positive in their perceptions of the EDEC package than those who tended towards a surface approach. This was particularly the case with regard to the use of animated media and may be attributed to the additional processing demands of animated media over other forms of delivery.

The observational element of the study highlighted a difference in approach to learning from one lab environment to another, with a far higher degree of collaborative learning taking place during the practical lab sessions that succeeded the EDEC sessions. Observation of the students during the three EDEC sessions highlighted a general lack of note-taking until the students were issued with accompanying workbooks. Where notes were taken, they often lacked structure, which made them unreliable during the subsequent practical lab sessions. There was also observational evidence of students having problems with or failing to process animated media. This led to a reliance by some students on the final frame of animations for conceptual processing which led to problems during subsequent lecturer questions that required conceptual process knowledge.

Chapter Five

Students' Use of EDEC - Case Study Three

5. Introduction

The third case study observed a sample of final year (4^{th} Year) undergraduate Electronics and Electrical Engineering students at a west of Scotland university. They were expected to complete a total of six EDEC modules within an overall timescale of six weeks, although the course lecturer intimated that he envisaged most students completing them during the first three weeks to allow time for a practical assignment to be completed during the final three weeks. Each session was timetabled to last for two hours. Support to the students was provided by the course lecturer who typically consulted with them on an individual basis at one point during each session to monitor progress and address any queries.

5.1. Background to the EDEC Modules

The EDEC modules that were used had been delivered by a number of courses in the Engineering Faculty over the previous five years. The materials had previously been presented from CD-Rom and were therefore being run for the first time via the Web. In preparation for Web-based delivery, teaching staff had developed a front-end website, which linked to the EDEC modules. This provided staff with the opportunity to incorporate other external Web links which offered further support and context to the learning which was offered through the EDEC modules.

5.1.1. The EDEC Lab Sessions

The six EDEC modules covered were intended to provide the students with a grounding in a number of topics and act as preparation for the practical lab sessions, culminating in an assessed assignment. Each student was expected to complete two EDEC modules per session. This was double the expectation of the two previous case studies however the students were expected to use the EDEC package outside of the timetabled sessions in order to complete the work. The responsibility for completion of the work was the students' and this led to their working at various stages of the modules by weeks two and three depending on the amount of independent study that they had undertaken over the week. The overall structure of the six-week block including details of the EDEC module topics is shown in Table 76.

Description of Session	
Week 1	EDEC lab session ▪ Combinational Circuits ▪ Storage and Clocked Devices
Week 2	EDEC lab session ▪ Concurrent Operations ▪ Data Transfers and Handshaking
Week 3	EDEC lab session ▪ Finite State Machines ▪ Test Benches
Week 4	Practical Lab Session
Week 5	Practical Lab Session
Week 6	Practical Lab Session

Table 76

The methods employed in the evaluation were intended to be consistent with those used during the previous case study. The course lecturer however expressed concern that the time taken for pre/post-testing would meet with resistance from the students due their approaching the completion of their degree. The measure was therefore replaced with a pre/post intervention confidence log (see Appendix M), which was designed to be more easily administered. The small sample size permitted the use of post-intervention focus groups with the students to discuss their perceptions of EDEC package alongside my observations during the sessions. A full breakdown of the measures used is shown in Table 77.

Area of Investigation	Methodologies
Cognitive styles assessment	Cognitive Styles Analysis test (CSA)
Student learning	Student observation Student questioning – Focus groups Confidence log
Learning strategies assessment	Revised Study Process Questionnaire (R-SPQ-2F)
Student motivation	Revised Study Process Questionnaire (R-SPQ-2F)
Student perceptions of the Web-based learning material	Questionnaire
Learning resource use	Learning Resource Questionnaire
Pedagogical issues	Course deliverer interview

Table 77

5.2. The Learning Environment

The learning environment that was used for the duration of the EDEC component of the course was a medium sized computer cluster inside a square shaped room. The computers were arranged in four rows as shown in Figure 19. Students selected their own preferred position and worked individually through the modules.

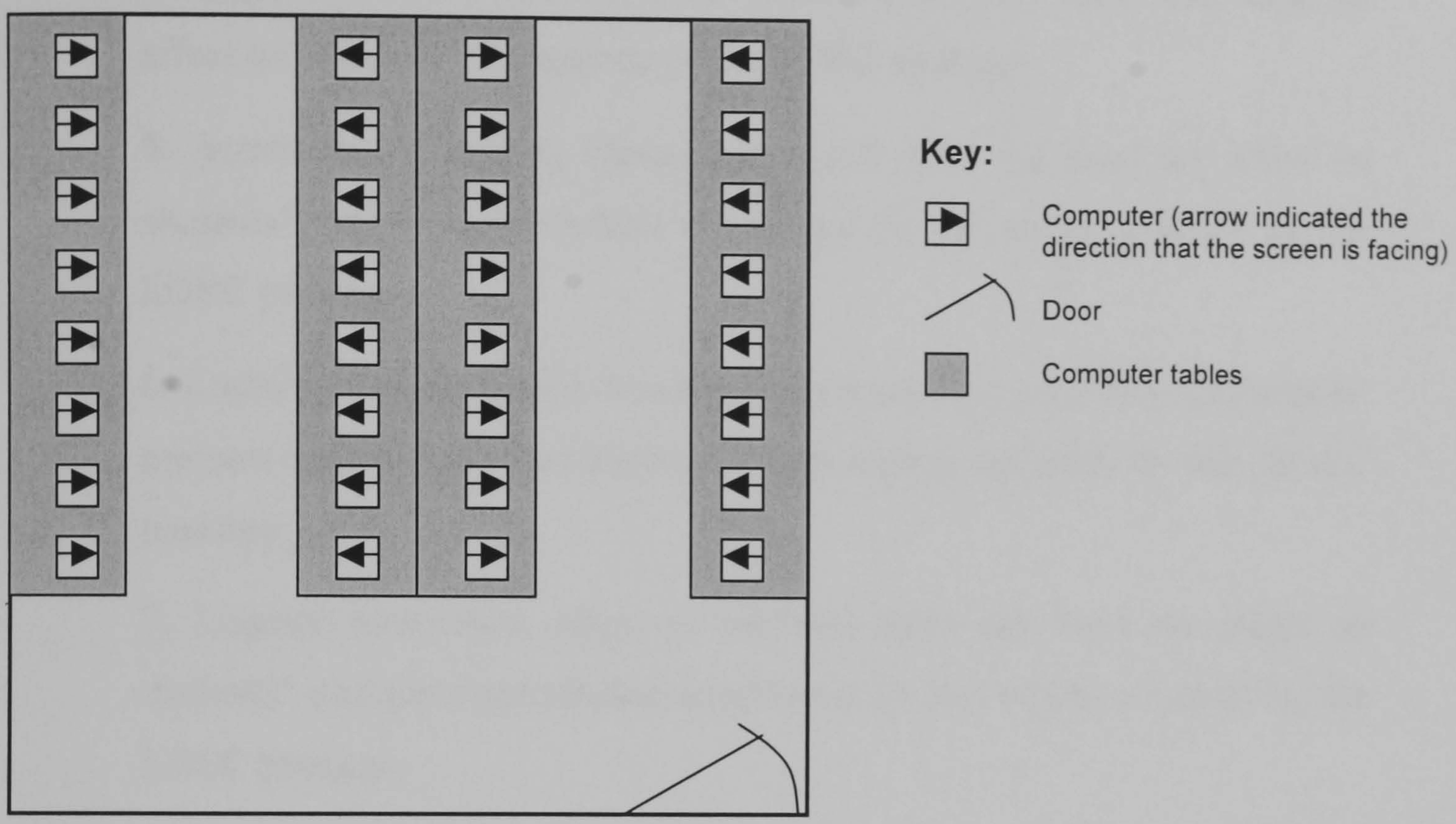


Figure 19

The room was used exclusively by the students during each EDEC session and the course lecturer provided individual support at a single point during each session. The students had access to printing facilities, although these were rarely used.

5.3. Outline of Hypotheses

Based on the same general hypotheses that certain groups of students may be disadvantaged by the method of delivery of media during their use of the EDEC resource, a number of hypotheses were developed. These were intended to test the students' cognitive style and approach to learning against their perceptions of EDEC and their confidence in a selection of topics covered by the EDEC modules. These were:

> **1.** Sensory cognitive style (verbaliser/imager) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

2. Organisational cognitive style (wholist/analytic) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

3. Sensory cognitive style (verbaliser/imager) does not have an affect on students' perceptions of the EDEC package.

4. Organisational cognitive style (wholist/analytic) does not have an affect on students' perceptions of the EDEC package.

5. Approach to learning (deep or surface) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

6. Learning strategy (deep or surface) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

7. Learner motivation (deep or surface) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

8. Approach to learning (deep or surface) does not have an affect on students' perceptions of the EDEC package.

9. Learning strategy (deep or surface) does not have an affect on students' perceptions of the EDEC package.

10. Learner motivation (deep or surface) does not have an affect on students' perceptions of the EDEC package.

5.4. Student Cognitive Styles

Riding's Cognitive Styles Analysis (CSA) test was administered to the sample before the second EDEC session to form the basis of a learning profile for each student in the sample. The test was again administered through individual floppy disks, which were distributed to each student at the start of the session. Compatibility and system checks were carried out prior to the test being administered as in Case Study 2. The students were given feedback on their responses via Riding's CSA interpretation sheet and this was supported by a brief discussion with each student at the end of the test. Table 78 gives a breakdown of cognitive style over both style dimensions for each of the twelve students who took part in the test. It should be noted that each student was assigned a number and the table therefore does not run consecutively due to a number of students who did not participate in the test.

Breakdown Cognitive Styles (N=12)		
Student No.	**Wholist/Analytic Style**	**Verbaliser/Imager Style**
Student 1	Wholist	Verbaliser
Student 2	Analytic	Bimodal
Student 3	Intermediate	Bimodal
Student 4	Intermediate	Verbaliser
Student 5	Wholist	Verbaliser
Student 6	Intermediate	Bimodal
Student 7	Analytic	Bimodal
Student 9	Wholist	Bimodal
Student 10	Intermediate	Imager
Student 11	Analytic	Bimodal
Student 13	Analytic	Bimodal
Student 14	Analytic	Imager

Table 78

There were no unusual results from the data collected from the administration of the test (Tables 79 and 80), based on Riding's criteria for validity, namely time taken to complete the test and the number of correct answers obtained. To this end the results obtained were regarded as valid for the sample.

	Wholist/Analytic Speed Index	**Verbaliser/Imager Speed Index**
Recorded Mean	5.60	2.84
Recorded Median	5.01	2.64
Std. Deviation	2.15	1.02
Minimum Required for Validity	2.75	1.74
Maximum Required for Validity	9.83	5.21

Table 79

	Wholist/Analytic % Correct	**Verbaliser/Imager % Correct**
Recorded Mean	97.33	91.17
Recorded Median	98.00	92.00
Std. Deviation	3.42	6.13
Minimum Required for Validity	88	75
Maximum Required for Validity	100	98

Table 80

5.5. Approach to Learning

The students' approach to learning was assessed using Biggs' Revised Study Process Questionnaire (R-SPQ-2F) in order to be consistent with the other two case studies. The results of the questionnaire showed that while the sample could generally be described as taking a deep approach to their learning, when broken down to deep/surface motivation and deep/surface strategy, the picture became more complex (Table 81). It should once again be noted that the table does not run consecutively due to two students who did not participate in the test.

Breakdown of Results from R-SPQ-2F (N=16)			
Student No.	**Deep/Surface Approach**	**Deep/Surface Motivation**	**Deep/Surface Strategy**
Student 2	Surface approach	Equal	Surface strategy
Student 3	Surface approach	Equal	Surface strategy
Student 4	Surface approach	Equal	Surface strategy
Student 5	Deep approach	Deep motivation	Deep strategy
Student 6	Surface approach	Surface motivation	Surface strategy
Student 8	Surface approach	Surface motivation	Surface strategy
Student 9	Deep approach	Deep motivation	Deep strategy
Student 10	Deep approach	Deep motivation	Deep strategy
Student 11	Deep approach	Deep motivation	Surface strategy
Student 12	Deep approach	Deep motivation	Deep strategy
Student 13	Deep approach	Deep motivation	Surface strategy
Student 14	Deep approach	Deep motivation	Surface strategy
Student 15	Deep approach	Deep motivation	Deep strategy
Student 16	Deep approach	Deep motivation	Deep strategy
Student 17	Deep approach	Deep motivation	Surface strategy
Student 18	Deep approach	Deep motivation	Surface strategy

Table 81

The results from the R-SPQ-2F were particularly interesting, as a greater difference between motivation and strategy was observed in this case study than the others. It could be speculated that this may have been due to the students' imminent completion of their degree course leading to a greater number of them demonstrating a surface strategy due to their short-term goals while maintaining a deep motivation to obtain as good a degree as possible.

5.6. Student Confidence

As discussed earlier, it was agreed with the course lecturer that a confidence log would be utilised in lieu of pre/post-testing during this case to evaluate a number of the topics covered by the EDEC modules. Topics were selected to reflect a cross-section of those covered across the six modules. The content of the confidence log was vetted and approved by the course deliverer prior to its administration, in order to eliminate inappropriate content and language. Analysis of the data clearly indicated that the EDEC package had contributed to the students' learning. Mean values of confidence before and after the EDEC modules are shown in Table 82.

Breakdown of Student Confidence Log Results Before and After EDEC

	N Responses	Mean	Std. Deviation
Define a finite state machine (pre-EDEC)	11	2.36	.67
Define a finite state machine (post-EDEC)	9	2.22	.67
Describe the architecture of a finite state machine (pre-EDEC)	11	2.64	.81
Describe the architecture of a finite state machine (post-EDEC)	9	2.33	.50
Produce a state transition network to describe a simple finite state machine (pre-EDEC)	11	2.55	1.29
Produce a state transition network to describe a simple finite state machine (post-EDEC)	9	2.33	.50
Convert a state transition network for a Moore machine into a Mealy machine (pre-EDEC)	10	3.60	.84
Convert a state transition network for a Moore machine into a Mealy machine (post-EDEC)	9	2.89	.93
Implement a simple finite state machine in VHDL (pre-EDEC)	11	4.18	.87
Implement a simple finite state machine in VHDL (post-EDEC)	9	2.78	1.09
Describe two situations in sychronous data transfer where a common clock between subsystems would be inappropriate (pre-EDEC)	11	3.91	.94
Describe two situations in sychronous data transfer where a common clock between subsystems would be inappropriate (post-EDEC)	9	2.33	.71
Give an example where asynchronous transfers are better than synchronous transfers (pre-EDEC)	11	2.82	1.17
Give an example where asynchronous transfers are better than synchronous transfers (post-EDEC)	9	2.11	.60
Implement a multiple handshaking routine in VHDL (pre-EDEC)	11	4.18	.87
Implement a multiple handshaking routine in VHDL (post-EDEC)	9	3.00	.87
Describe a testbench (pre-EDEC)	11	3.55	.93
Describe a testbench (post-EDEC)	8	2.63	.74
Whilst exhaustive testing is impractical, describe the two elements of a testbench which must undergo testing (pre-EDEC)	11	3.91	1.04
Whilst exhaustive testing is impractical, describe the two elements of a testbench which must undergo testing (post-EDEC)	8	3.13	.83
Design a testbench for an ALU using VHDL (pre-EDEC)	11	4.27	.90
Design a testbench for an ALU using VHDL (post-EDEC)	8	3.13	.83

Note: Mean values correspond to the following:
1 – Very confident, 2 – Confident, 3 – Some confidence, 4 – Little confidence, 5 – No confidence at all

Table 82

From the table it can be seen that the mean score for confidence level decreased across all of the topics that were covered by the confidence log, indicating that the modules had made the students more confident in the topics covered. When each of the eleven tasks covered by the confidence log was considered individually (Table 83), a high degree of prior knowledge was evident during the first four tasks. This was confirmed by the course lecturer who indicated that these tasks were regarded as prerequisites for the VHDL (Very High Speed

Integrated Circuit Hardware Description Language) questions that followed and would incorporate a degree of prior knowledge.

Breakdown of Student Confidence Log Results – Frequency of Response (n=10/11, pre-intervention and n=8/9, post-intervention)					
EDEC Topic	**very confident**	**confident**	**some confidence**	**little confidence**	**no confidence at all**
1. Define a finite state machine (pre-EDEC)	1	5	5		
1. Define a finite state machine (post-EDEC)	1	5	3		
2. Describe the architecture of a finite state machine (pre-EDEC)		6	3	2	
2. Describe the architecture of a finite state machine (post-EDEC)		6	3		
3. Produce a state transition network to describe a simple finite state machine (pre-EDEC)	2	5	1	2	1
3. Produce a state transition network to describe a simple finite state machine (post-EDEC)		6	3		
4. Convert a state transition network for a Moore machine into a Mealy machine (pre-EDEC)			6	2	2
4. Convert a state transition network for a Moore machine into a Mealy machine (post-EDEC)		3	5		1
5. Implement a simple finite state machine in VHDL (pre-EDEC)			3	3	5
5. Implement a simple finite state machine in VHDL (post-EDEC)	1	2	5		1
6. Describe two situations in synchronous data transfer where a common clock between subsystems would be inappropriate (pre-EDEC)			5	2	4
6. Describe two situations in synchronous data transfer where a common clock between subsystems would be inappropriate (post-EDEC)	1	4	4		
7. Give an example where asynchronous transfers are better than synchronous transfers (pre-EDEC)	2	1	6	1	1
7. Give an example where asynchronous transfers are better than synchronous transfers (post-EDEC)	1	6	2		
8. Implement a multiple handshaking routine in VHDL (pre-EDEC)			3	3	5
8. Implement a multiple handshaking routine in VHDL (post-EDEC)		2	6		1
9. Describe a testbench (pre-EDEC)		1	5	3	2
9. Describe a testbench (post-EDEC)		4	3	1	
10. Whilst exhaustive testing is impractical, describe the two elements of a testbench which must undergo testing (pre-EDEC)		1	3	3	4
10. Whilst exhaustive testing is impractical, describe the two elements of a testbench which must undergo testing (post-EDEC)		1	6		1
11. Design a testbench for an ALU using VHDL (pre-EDEC)			3	2	6
11. Design a testbench for an ALU using VHDL (post-EDEC)		1	6		1

Table 83

5.6.1. Student Confidence and Cognitive Style

In order to establish whether cognitive style had played a role in determining student confidence in the topics covered by the EDEC package, the following hypotheses were tested:

1. Sensory (verbaliser/imager) cognitive style does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

2. Organisational (wholist/analytic) cognitive style does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

Although twelve students completed the Cognitive Styles Analysis test, only seven of these completed both confidence logs. When the change in each student's confidence (difference between pre and post-EDEC confidence log scores) was compared with their ratios over both cognitive style dimensions there was little evidence of any relationship between cognitive style and confidence differential (Tables 84 and 85). There was however one confounding result obtained for student 7 who achieved a differential score of -5 between the two confidence logs. It was assumed that this may have been a deliberately erroneous response on the part of the student, although there was no further qualitative evidence to base this assumption on.

Comparison of Organisational Cognitive Style and Confidence Differential		
Student No.	Wholist/Analytic Ratio	Confidence Differential
9	.96	2
1	.98	3
10	1.13	3
3	1.16	6
6	1.25	23
7	1.79	-5
13	2.02	2

Table 84

Comparison of Sensory Cognitive Style and Confidence Differential		
Student No.	Verbaliser/Imager Ratio	Confidence Differential
1	.90	3
13	1.02	2
6	1.03	23
7	1.04	-5
9	1.05	2
3	1.07	6
10	1.47	3

Table 85

Although the small sample size limited the use of statistical testing the analyses indicated that there was no observable relationship between cognitive style and student confidence and hypotheses 1 and 2 would therefore be upheld in each instance.

5.6.2. Student Confidence and Approach to Learning

Based on the general hypothesis that approach to learning may have had an effect on the student's confidence in the topics covered by EDEC the following hypotheses were tested:

> **5.** Approach to learning (deep or surface) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.
>
> **6.** Learning strategy (deep or surface) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.
>
> **7.** Learner motivation (deep or surface) does not have an affect on students' pre/post-intervention confidence in the topics covered by the EDEC package.

Because of the limited sample of students who completed both confidence logs and the R-SPQ-2F, the initial comparison was made through the rank ordering of each R-SPQ-2F category and comparing the scores with each student's differential confidence score (Tables 86 to 91). The results generally indicated no relationship between any of the R-SPQ-2F categories and differential confidence with the exception of the surface approach scale where a relationship was observed. Subsequent analysis using Spearman's bivariate test confirmed the relationship (corr. coeff. = 0.812, p=0.05), although the small sample size has to be taken into account in this analysis.

Comparison of R-SPQ-2F Results for Deep Approach to Learning and Confidence Differential		
Student No.	Deep approach	Confidence Differential
3	22	6
13	22	2
6	23	23
9	26	2
10	29	3
5	31	9

Table 86

Comparison of R-SPQ-2F Results for Surface Approach to Learning and Confidence Differential		
Student No.	Surface approach	Confidence Differential
10	12	3
9	18	2
13	20	2
3	24	6
5	25	9
6	27	23

Table 87

Comparison of R-SPQ-2F Results for Deep Strategy and Confidence Differential		
Student No.	Deep strategy	Confidence Differential
3	11	6
13	12	2
9	13	2
6	14	23
10	15	3
5	16	9

Table 88

Comparison of R-SPQ-2F Results for Surface Strategy and Confidence Differential		
Student No.	Surface strategy	Confidence Differential
10	6	3
9	11	2
3	13	6
13	14	2
5	14	9
6	16	23

Table 89

Comparison of R-SPQ-2F Results for Deep Motivation and Confidence Differential		
Student No.	Deep motive	Confidence Differential
6	9	23
13	10	2
3	11	6
9	13	2
10	14	3
5	15	9

Table 90

Comparison of R-SPQ-2F Results for Surface Motivation and Confidence Differential		
Student No.	Surface motive	Confidence Differential
13	6	2
10	6	3
9	7	2
6	11	23
3	11	6
5	11	9

Table 91

Based on the analysis of the data available, one may tentatively conclude that strategy and motivation had no effect on the students' confidence differential in the topics covered by EDEC, while overall approach did have an affect. This conclusion would lead to the rejection of hypothesis 5, while both hypotheses 6 and 7 would be upheld.

5.7. Student Perceptions

At the end of the six-week block, the students were asked for their perceptions of the EDEC material and how well it supported their practical lab work. This was achieved through the administration of a questionnaire (Appendix A), which was supplemented by two focus groups that were held over the final two weeks of the study. The questionnaire covered the following categories:

1. Learnability of the EDEC interface
2. Navigability of the EDEC interface
3. Quality of the EDEC interface
4. Graphic and interactive elements
5. Overall student perceptions
6. Computer and Internet

The focus groups lasted for around fifteen minutes each, and all students who were present participated. Due to the fact that this particular sample of students were within a few weeks of the completion of their degree I felt that the questioning format employed during the observation of student use of the EDEC materials in both of the previous case studies was inappropriate in this instance. This became very obvious during the first session, where the students appeared to be very focused towards the work in hand. It was felt that the previous format of questioning students during the intervention would be counterproductive to the research and my relationship with the students. After some consideration, which was informed by discussion with the course lecturer and the students themselves, it was decided that a short focus group at the end of two of the three sessions would offer greatest benefit to the research as a whole.

The students' responses on the learnability of EDEC were generally positive (Table 92), although a number of them indicated that they had experienced problems with parts of the system due to the lack of help provided when they became confused. Discussion during both focus groups indicated that the main problem centred around the need to simultaneously use EDEC and a separate simulation package for completion of the assignment. This proved to be problematic, as it was difficult to use EDEC alongside other software simultaneously, contradicting EDEC's own aims for the software at the development stage. One student commented,

> *"You can't do the simulations and then click on the window to find what you want because the package doesn't allow you to do that."*

Results of Learnability of EDEC Interface – Frequency of Responses (n=16)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I could follow the instructions clearly.	0	1	6	8	1
I quickly became familiar with the system.	0	2	2	9	3
Parts of the system were difficult to use.	3	6	2	5	0
The instructions on screen were sufficient when needed.	0	0	10	6	0
The system helped me if I got confused.	1	4	11	0	0

Table 92

Although the respondents were generally comfortable with their ability to navigate through the materials, half of them indicated problems with the structure of EDEC (Table 93).

Results of Navigability of EDEC Interface – Frequency of Responses (n=16)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
It was clear to me where I was in the system.	0	4	4	8	0
It was clear how to move through the system.	0	2	5	6	3
I think that the system is generally well structured.	2	6	5	1	2

Table 93

The negative response provided a further indication of the problems that the students had in working between EDEC and other software. From a software development perspective, this was most likely a consequence of the repurposing of EDEC from a standalone computer-based software resource to a Web-based resource that offered more flexible approaches to the learning environment than those envisaged during its original development. The students' familiarity with usability and navigation conventions employed in the standard Windows™

interface prompted a preference for the same approach to the EDEC interface as expressed during the first focus group. Although it was possible to leave the EDEC interface without closing it down altogether, the students' appeared to have developed a cognitive map of how to do this which was based on Windows™ conventions, resulting in a more negative perception of the EDEC interface.

The students' perceptions of the general quality of EDEC and its content highlighted a number of issues which related to the observation of their use of the package (Table 94).

Results of Quality of EDEC Interface – Frequency of Responses (n=16)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I found that the information was presented consistently.	0	0	12	4	0
It was obvious how to use the icons (buttons).	0	2	9	3	2
The language was clear.	0	2	7	6	1
I could easily read from the screen.	0	2	4	8	2
The screen colour did not interfere with my reading.	1	3	3	9	0
I got what I wanted from the system quickly.	2	9	5	0	0
Overall, the system had an attractive presentation.	2	7	5	2	0
There was too much information on each page for me to remember.	0	2	8	3	3
There was too much information which I didn't need to know.	0	5	6	4	1

Table 94

While they were ambivalent in their perceptions of the consistency of the presentation of information, they were more negative in their perceptions of the processing and use of information. Problems with the processing of information were highlighted in the students' responses to the statement, *'There was too much information on each page for me to remember'*. Only two of the sixteen respondents disagreed with the statement. When this issue was discussed during the two focus groups, it emerged that many of the students had experienced problems with the conflicting demands of processing textual and animated material simultaneously, and on occasions while taking notes. One student said

"If you're trying to see an animation and read text at the same time, and the text changes each time a new animation occurs, it's too difficult to take both in."

Two further comments from students during the second focus group indicated their preference for the use of an audio soundtrack for instructional narrative over the on-screen written text employed by EDEC. The comments highlighted the problems that can arise from the delivery of more than one form of media through the same perceptual channel.

Comment 1 - *"Personally, I did for my (final year) project Comnet and it's got animations and someone narrates all the way through the animations, and that's a lot easier to understand. Because basically you can listen to what the person's saying, but you can what the screen and just take notes."*

Comment 2 - *"For my project, I got this interactive CD from Agilent. They've got this software called V6 and that was really good. It does the animations, then there was a voice through it telling you what was happening and I thought that if this was the same as the EDEC stuff, I would have picked it up a lot better."*

There was also evidence to suggest that processing problems were related to the students' strategies in working through the modules. There were a number of observed instances of students initiating animated material while taking notes or while processing introductory text leading to a breakdown in their ability to process the concept being demonstrated. The results also indicated a degree of goal-orientation in the students' approach to EDEC. This was perhaps best demonstrated in the generally negative response to the statement, *'I got what I wanted from the system quickly'*. When this was discussed with them during the focus groups they described EDEC as being *'no more than an electronic book'* and indicated that it was not the most efficient way for them to gather knowledge. In fact, the majority of those present agreed that they would have preferred to have worked with a hardcopy book instead of EDEC.

The students were more critical of the visual aspects of the user interface in this case study than any of the others. They implied during one of the focus groups that this contributed to their generally negative perception of the package. A number of them referred to the user interface as being *'quite old-fashioned'* and *'very outdated'*. Three separate student comments highlighted the detrimental impact of the user interface on their perceptions of the package as learning resource.

Comment 1 - *"I think that if the package was as modern and up to date as we're saying it should be, then we might be telling you something completely different. We might be telling you that it was a worthwhile way of doing it."*

Comment 2 – *"It (the interface) puts you off right from the start; it put me off right from the start."*

Comment 3 – *"Outdated and discouraging. Just too dated, navigation may be obvious but it is not friendly, also it is quite off-putting."*

The problems experienced in processing information were further evidenced in the students' responses to statements relating to the graphic, animated and interactive elements of the EDEC package (Table 95).

Evaluation of Graphic, Animated and Interactive Elements – Frequency of Responses (n=16 or 7*)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I thought that the graphics were clear and helpful.	0	5	4	6	1
I thought that the interactive elements were difficult to find.	0	10	3	3	0
I found the animated elements too fast.	1	3	2	7	3
I felt that the animated elements would have been better if I could control speed and stop/start.	0	1	2	4	9
The use of images to support text was useful.	0	0	5	9	2
There was too much happening at one time with some animations.*	0	1	2	3	1
The animations were too long.*	0	4	2	0	1

Table 95

While the students recognised the benefits that static images and animation offered their learning, many considered the animated elements to be too fast to allow effective information processing of the concept being demonstrated. A number of comments made during the second focus group highlighted the problems encountered by a number of the students.

> **Comment 1** - *"It would all happen so fast and you couldn't slow it down and you're trying to read it, while watching it and you've no control over it."*
>
> **Comment 2** - *"There's so much happening in a single step. You start to repeat again and again and again and then you read it and then you watch it again to clarify what was going on."*

The lack of any ability to control the speed and the starting and stopping of animations when desired was raised on a number of occasions. While most of the students indicated that the animations were too fast, one took the opposite view during one of the focus groups, indicating that he in fact found them too slow. This particular student was observed to use a multiple review approach to the animations; taking notes as he processed the on-screen information. The problem he encountered while breaking the animations down to manageable 'chunks' was that he had to sit through the entire animation to get to the chunk of information that he wished to assimilate. He commented,

> *"Then you get to the next step and you couldn't go a step back. You'd have to continue to the end."*

Another student highlighted the lack of depth of interaction available to students and recognised the need to motivate the learner through interactive stimulus and continuous assessment to avoid a surface approach to the processing of information.

> *Although the EDEC system is a good method of conveying subject matter, it depends on the student, the interactive elements should contain more Q&As to prevent students skipping through pages and not learning the given material.*

The issue of students skimming over animated material was a consistent one encountered during each of the observations and will be discussed in more detail in chapter 7.

The students' overall perceptions of EDEC also had a generally negative tendency as demonstrated in Table 96.

Overall Student Perceptions of EDEC System – Frequency of Responses (n=16 or 7*)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Overall, I liked using the system.	4	7	4	1	0
I would use this system again in my studying.	8	4	2	2	0
I would recommend the system to other students.	6	5	3	2	0
The EDEC modules prepared me well for the lab sessions.*	2	1	2	1	1

Table 96

A number of students indicated that they had found EDEC a *'very time-consuming'* way of learning, with one referring to it as, *'so monotonous and boring'* and another commenting that although they had been expected to have completed the modules three weeks previously, *'most people here are still completing the modules just now'*. During the focus group discussion a number of students agreed with my observation that they appeared to be 'skimming over' content in order to complete the modules. One student went so far as to say, *'I don't know anything'*, based on his EDEC experience. The responses were also less than encouraging with regard to how well the EDEC modules had prepared them for the subsequent practical lab sessions which would form the basis for the assessed assignment. Only two out of seven students agreed that EDEC had prepared them well for the subsequent practical labs

The students were also asked to respond to a number of general statements regarding their use of computers and the Internet in order to compare these perceptions with those provided on EDEC (Table 97). The results indicated that they were generally ambivalent to the use of computer packages in their learning, although they were generally more positive than those given for EDEC. As perhaps would have been expected for students in the final year of their degree, the Internet figured prominently in their learning, although one student did highlight the sometimes *'extremely dubious'* nature of its content.

Computer and Internet Perceptions – Frequency of Responses (n=6, 7* or 13**)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I like to learn using computer packages.	1	3	10	2	0
I like to play games on a computer.*	1	3	2	1	0
The Internet is very useful to my learning.	0	0	3	7	6
	Less than once a month	**Around once a week**	**3 or 4 time a week**	**Most days**	**Never used one**
How often do you use a computer?	0	0	0	16	0
How often do you use the Internet?	0	0	2	14	0
	Own use	**Coursework/project research**		**Shopping**	**Other**
What do you use the Internet most for?**	6	7		0	0

Table 97

Wider discussion on the students' use of EDEC during the focus groups considered their patterns of use of the package. When they were asked during the first focus group if they had plans to use EDEC off-campus around 50-60% of the class said that they would. I followed up on this during the second focus group and was informed that all of the class had in fact accessed EDEC off-campus during the previous week; typically on a home computer. This raised a number of issues regarding problems with bandwidth leading to slow and ineffective use of the package, which led to a degree of frustration. A number of students highlighted the fact that they had been unable to access EDEC from home or halls at weekends. When I checked this with the course lecturer he indicated that this was due to university's policy of carrying out server maintenance during weekends.

5.8. Learning Resource Questionnaire

A Learning Resource Questionnaire was administered at the end of the six sessions in order to gain an insight into the students' resource preferences. The results indicated that traditional lectures coupled with the students' own notes were their preferred resources (Table 98).

Usefulness of Resource – Frequency of Responses					
	Useless	**Not very useful**	**Useful**	**Vital**	**Not sure**
Lectures (n=16)	2	0	4	9	1
Textbook(s) (n=15)	2	1	6	6	0
EDEC computer package (n=16)	1	7	8	0	0
Own notes from lectures/labs (n=15)	0	1	6	8	0
Borrowed notes from someone else (n=13)	3	4	5	0	1
Discussions with tutor/lecturer (n=14)	1	0	10	3	0
Discussions with other students (n=16)	0	2	9	5	0
Other resources (n=13)	0	2	9	1	1

Table 98

While half of the respondents indicated that the EDEC modules were useful to their learning, none regarded it as a vital resource. It can also be seen from the results that the students rated face to face interaction highly, whether with the course lecturer or other students. One student alluded to the tendency among some students to perceive EDEC as their sole resource, indicating that he would have perhaps preferred a more traditional approach through textbooks.

> *"EDEC was of use with regard to the course but should have been complemented more strongly by a related text book to offer personal choice of learning method, in my opinion this was not the case."*

Interestingly, when the learning resources preference data was compared with the students' results from the R-SPQ-2F, strongly significant positive relationships were observed between the deep scales and the usefulness of lectures (Table 99). Similar comparisons made between cognitive style and the usefulness of particular resources identified no relationship between resource preference and cognitive style.

Comparison of R-SPQ-2F Results and Students' Perceptions of Usefulness of Lectures

			Lectures
Spearman's rho	Deep approach	Correlation Coefficient	.719**
		Sig. (2-tailed)	.002
		N	16
	Surface approach	Correlation Coefficient	-.059
		Sig. (2-tailed)	.828
		N	16
	Deep strategy	Correlation Coefficient	.732**
		Sig. (2-tailed)	.001
		N	16
	Surface strategy	Correlation Coefficient	-.033
		Sig. (2-tailed)	.903
		N	16
	Deep motive	Correlation Coefficient	.654**
		Sig. (2-tailed)	.006
		N	16
	Surface motive	Correlation Coefficient	-.080
		Sig. (2-tailed)	.767
		N	16

**. Correlation is significant at the .01 level (2-tailed).

Table 99

5.9. Student Perceptions and Cognitive Style

The relationship between the learner's cognitive style and their perceptions of the EDEC material was explored through bivariate analysis of selected data collected from the Cognitive Styles Analysis test and the perceptions questionnaire. The same hypotheses that were tested during the second case study were applied to this one in order to be consistent. Since the sample size for this particular case study was low, statistical analysis was carried out purely to provide an indication of correlation for comparison with the results obtained from the second case study. The following hypotheses were tested:

3. Sensory (verbaliser/imager) cognitive style does not have an affect on students' perceptions of the EDEC package.
4. Organisational (wholist/analytic) cognitive style does not have an affect on students' perceptions of the EDEC package.

The analysis of students' perceptions of the learnability of EDEC against cognitive style demonstrated no significant relationships (Table 100). However the results for sensory cognitive style indicated a more positive perception of issues relating to ease of use among imager students than their verbaliser counterparts.

Comparison of Cognitive Style and the Students' Perceptions of the Learnability of EDEC

			Wholist/Analytic Ratio	Verbal/Imager Ratio
Spearman's rho	I could follow the instructions clearly.	Correlation Coefficient	.107	.541
		Sig. (2-tailed)	.768	.106
		N	10	10
	I quickly became familiar with the system.	Correlation Coefficient	-.082	.606
		Sig. (2-tailed)	.822	.063
		N	10	10
	Parts of the system were difficult to use.	Correlation Coefficient	-.114	-.418
		Sig. (2-tailed)	.753	.230
		N	10	10
	The instructions on screen were sufficient when needed.	Correlation Coefficient	.261	.175
		Sig. (2-tailed)	.466	.629
		N	10	10
	The system helped me if I got confused.	Correlation Coefficient	-.437	-.153
		Sig. (2-tailed)	.207	.673
		N	10	10

Table 100

The comparison of cognitive style and students perceptions of the navigability of EDEC also provided no evidence of any relationship (Table 101).

Comparison of Cognitive Style and the Students' Perceptions of the Navigability of EDEC

			Wholist/Analytic Ratio	Verbal/Imager Ratio
Spearman's rho	It was clear to me where I was in the system.	Correlation Coefficient	-.303	-.028
		Sig. (2-tailed)	.395	.940
		N	10	10
	It was clear how to move through the system.	Correlation Coefficient	-.052	.134
		Sig. (2-tailed)	.886	.712
		N	10	10
	I think that the system is generally well structured.	Correlation Coefficient	-.229	.057
		Sig. (2-tailed)	.525	.875
		N	10	10

Table 101

There was a significant relationship observed between respondents' perceptions of the attractiveness of the EDEC interface and the wholist/analytic dimension, with wholist students demonstrating a more positive perception than analytic students. The analysis also suggested that wholist students were also more likely to consider that there was too much information that they didn't need to know than their analytic counterparts (Table 102). Interestingly, no significant relationship was observed between perceptions relating to information processing and cognitive style over either dimension indicating that the students' perceptions of their ability to process information from EDEC was independent of cognitive style.

Comparison of Cognitive Style and the Students' Perceptions of the Quality of EDEC

			Wholist/Analytic Ratio	Verbal/Imager Ratio
Spearman's rho	I found that the information was presented consistently.	Correlation Coefficient	-.087	.262
		Sig. (2-tailed)	.811	.465
		N	10	10
	It was obvious how to use the icons (buttons).	Correlation Coefficient	-.206	.117
		Sig. (2-tailed)	.569	.748
		N	10	10
	The language was clear.	Correlation Coefficient	.112	.033
		Sig. (2-tailed)	.758	.928
		N	10	10
	I could easily read from the screen.	Correlation Coefficient	-.165	.360
		Sig. (2-tailed)	.648	.307
		N	10	10
	The screen colour did not interfere with my reading.	Correlation Coefficient	.172	.618
		Sig. (2-tailed)	.635	.057
		N	10	10
	I got what I wanted from the system quickly.	Correlation Coefficient	-.493	-.293
		Sig. (2-tailed)	.148	.412
		N	10	10
	Overall, the system had an attractive presentation.	Correlation Coefficient	-.724*	.081
		Sig. (2-tailed)	.018	.825
		N	10	10
	There was too much information on each page for me to remember.	Correlation Coefficient	-.303	-.146
		Sig. (2-tailed)	.395	.688
		N	10	10
	There was too much information which I didn't need to know.	Correlation Coefficient	-.610	.182
		Sig. (2-tailed)	.061	.615
		N	10	10

*. Correlation is significant at the .05 level (2-tailed).

Table 102

The analysis of the students' perceptions of the graphic, animated and interactive elements against cognitive style tended to indicate that verbaliser students had more difficulty in finding interactive elements and in information processing from animation than those who tended towards the analytic end of the dimension (Table 103). These findings challenged those for the larger sample during the second case study, where no relationship between sensory cognitive style and perception was observed.

Comparison of Cognitive Style and the Students' Perceptions of the Graphic, Animated and Interactive Elements of EDEC

			Wholist/Analytic Ratio	Verbal/Imager Ratio
Spearman's rho	I thought that the graphics were clear and helpful.	Correlation Coefficient	.045	.322
		Sig. (2-tailed)	.902	.364
		N	10	10
	I thought that the interactive elements were difficult to find.	Correlation Coefficient	-.487	-.548
		Sig. (2-tailed)	.154	.101
		N	10	10
	I found the animated elements too fast.	Correlation Coefficient	-.407	-.488
		Sig. (2-tailed)	.243	.153
		N	10	10
	I felt that the animated elements would have been better if I could control speed and stop/start.	Correlation Coefficient	-.135	-.766**
		Sig. (2-tailed)	.710	.010
		N	10	10
	The use of images to support text was useful.	Correlation Coefficient	.141	-.060
		Sig. (2-tailed)	.698	.868
		N	10	10
	There was too much happening at one time with some animations.	Correlation Coefficient	.316	-.949
		Sig. (2-tailed)	.684	.051
		N	4	4
	The animations were too long.	Correlation Coefficient	-.316	-.316
		Sig. (2-tailed)	.684	.684
		N	4	4

**. Correlation is significant at the .01 level (2-tailed).

Table 103

Finally, when the students' overall perceptions of EDEC were compared with cognitive style no significant relationships were evident (Table 104).

Comparison of Cognitive Style and the Students' Overall Perceptions EDEC

			Wholist/Analytic Ratio	Verbal/Imager Ratio
Spearman's rho	Overall, I liked using the system.	Correlation Coefficient	-.221	-.547
		Sig. (2-tailed)	.540	.102
		N	10	10
	I would use this system again in my studying.	Correlation Coefficient	-.382	-.518
		Sig. (2-tailed)	.276	.125
		N	10	10
	I would recommend the system to other students.	Correlation Coefficient	-.509	-.289
		Sig. (2-tailed)	.133	.418
		N	10	10
	The EDEC modules prepared me well for the lab sessions.	Correlation Coefficient	-.200	-.600
		Sig. (2-tailed)	.800	.400
		N	4	4

Table 104

Overall, the analysis of perception against cognitive style indicated no relationship strong enough to challenge the two hypotheses outlined earlier. The contradiction between those relationships that were found to be significant for this sample and those from the second case study would also tend to highlight the need for caution in the interpretation of the data due to the limited sample size in this instance.

5.10. Student Perceptions and Approach to Learning

The comparison of the results obtained from the R-SPQ-2F and the students' perception of EDEC used the same three hypotheses that were applied during the first two cases studies. These were:

> **8.** Approach to learning (deep/surface) does not have an affect on students' perceptions of the EDEC package.
>
> **9.** Learning strategy (deep/surface) does not have an affect on students' perceptions of the EDEC package.
>
> **10.** Learner motivation (deep/surface) does not have an affect on students' perceptions of the EDEC package.

While the sample size once again limited the statistical significance of any analyses undertaken, the general trends that were observable in the data provided an insight into any relationships that were present. The analysis of the students' perceptions of the learnability of EDEC against their R-SPQ-2F results indicated a number of significant relationships between perception and deep learning scales (Table 105). The most obvious of these came in the form of strongly significant negative correlations between each of the deep scales (approach, strategy and motivation) and the students' response to the statement, *'Parts of the system were difficult to use'* (corr. coeffs. -0.802, -0.712 and -0.798, p=0.0002, 0.002 and 0.0002 respectively). In general the significance of the relationships indicated that the higher the student scored on the deep scales from the R-SPQ-2F, the more positive they were in their perceptions of the learnability of EDEC.

Comparison of R-SPQ-2F Results and the Students' Perceptions of the Learnability of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I could follow the instructions clearly.	Correlation Coefficient	.623**	-.059	.569*	-.103	.604*	.047
		Sig. (2-tailed)	.010	.830	.021	.704	.013	.863
		N	16	16	16	16	16	16
	I quickly became familiar with the system.	Correlation Coefficient	.527*	.162	.478	.083	.513*	.246
		Sig. (2-tailed)	.036	.549	.061	.760	.042	.359
		N	16	16	16	16	16	16
	Parts of the system were difficult to use.	Correlation Coefficient	-.802**	-.105	-.712**	-.048	-.798**	-.194
		Sig. (2-tailed)	.0002	.698	.002	.859	.0002	.471
		N	16	16	16	16	16	16
	The instructions on screen were sufficient when needed.	Correlation Coefficient	.398	.281	.425	.283	.343	.188
		Sig. (2-tailed)	.127	.292	.101	.289	.194	.485
		N	16	16	16	16	16	16
	The system helped me if I got confused.	Correlation Coefficient	.092	-.522*	.165	-.502*	-.120	-.425
		Sig. (2-tailed)	.735	.038	.542	.048	.658	.101
		N	16	16	16	16	16	16

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 105

The relationship between the R-SPQ-2F results over the three deep learning scales and perceptions carried over to the analysis of the students perceptions of the navigability of EDEC (Table 106). In particular, a strongly significant positive relationship was observed between the three deep scales and the students perceptions of how well structured the EDEC package was (corr. coeffs. 0.723, 0.707 and 0.672, p=0.002, 0.002 and 0.004 respectively).

Comparison of R-SPQ-2F Results and the Students' Perceptions of the Navigability of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	It was clear to me where I was in the system.	Correlation Coefficient	.230	.266	.220	.132	.163	.472
		Sig. (2-tailed)	.390	.319	.413	.626	.547	.065
		N	16	16	16	16	16	16
	It was clear how to move through the system.	Correlation Coefficient	.416	.080	.457	.023	.343	.095
		Sig. (2-tailed)	.109	.767	.075	.934	.193	.727
		N	16	16	16	16	16	16
	I think that the system is generally well structured.	Correlation Coefficient	.723**	-.067	.707**	-.091	.672**	-.036
		Sig. (2-tailed)	.002	.805	.002	.736	.004	.896
		N	16	16	16	16	16	16

**. Correlation is significant at the .01 level (2-tailed).

Table 106

The general trend continued into the analysis of variables relating to the quality of EDEC with a number of significant relationships observed (Table 107). There was however no relationship observed for either of the two statements relating to information processing; *'I got what I wanted from the system quickly'*, and *'there was too much information on each page for me to remember'*.

Comparison of R-SPQ-2F Results and the Students' Perceptions of the Quality of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I found that the information was presented consistently.	Correlation Coefficient	.477	-.063	.428	-.047	.479	-.097
		Sig. (2-tailed)	.062	.817	.098	.862	.061	.721
		N	16	16	16	16	16	16
	It was obvious how to use the icons (buttons).	Correlation Coefficient	.468	-.237	.380	-.297	.468	-.008
		Sig. (2-tailed)	.068	.377	.147	.264	.067	.975
		N	16	16	16	16	16	16
	The language was clear.	Correlation Coefficient	.517*	.148	.485	.096	.488	.215
		Sig. (2-tailed)	.040	.583	.057	.724	.055	.424
		N	16	16	16	16	16	16
	I could easily read from the screen.	Correlation Coefficient	.598*	.040	.490	-.061	.602*	.159
		Sig. (2-tailed)	.014	.884	.054	.823	.014	.556
		N	16	16	16	16	16	16
	The screen colour did not interfere with my reading.	Correlation Coefficient	.585*	.070	.613*	-.041	.439	.206
		Sig. (2-tailed)	.017	.795	.012	.880	.089	.445
		N	16	16	16	16	16	16
	I got what I wanted from the system quickly.	Correlation Coefficient	.034	-.132	-.004	-.235	.022	.144
		Sig. (2-tailed)	.902	.627	.988	.381	.936	.594
		N	16	16	16	16	16	16
	Overall, the system had an attractive presentation.	Correlation Coefficient	.377	-.351	.307	-.444	.265	-.035
		Sig. (2-tailed)	.150	.183	.248	.085	.321	.898
		N	16	16	16	16	16	16
	There was too much information on each page for me to remember.	Correlation Coefficient	.077	-.058	.035	-.008	.052	-.056
		Sig. (2-tailed)	.776	.831	.897	.977	.847	.836
		N	16	16	16	16	16	16
	There was too much information which I didn't need to know.	Correlation Coefficient	-.098	-.008	-.204	-.033	.037	.088
		Sig. (2-tailed)	.718	.977	.448	.904	.892	.746
		N	16	16	16	16	16	16

*. Correlation is significant at the .05 level (2-tailed).

Table 107

The analysis of data relating to the students' perceptions of the graphic, animated and interactive elements once again indicated that those who scored highly on the deep scales had fewer problems with these elements than those who did not (Table 108). The results indicated that students with a surface tendency were more likely to experience information processing problems related to choice of media than those who scored highly on the deep scales.

Comparison of R-SPQ-2F Results and the Students' Perceptions of the Graphic, Animated and Interactive Elements of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	I thought that the graphics were clear and helpful.	Correlation Coefficient	.518*	.054	.464	.001	.529*	.181
		Sig. (2-tailed)	.040	.842	.070	.998	.035	.502
		N	16	16	16	16	16	16
	I thought that the interactive elements were difficult to find.	Correlation Coefficient	-.476	.369	-.514*	.311	-.412	.488
		Sig. (2-tailed)	.063	.159	.041	.241	.113	.055
		N	16	16	16	16	16	16
	I found the animated elements too fast.	Correlation Coefficient	-.602*	.389	-.647**	.420	-.462	.234
		Sig. (2-tailed)	.014	.137	.007	.106	.072	.383
		N	16	16	16	16	16	16
	I felt that the animated elements would have been better if I could control speed and stop/start.	Correlation Coefficient	-.531*	.053	-.475	.168	-.436	-.154
		Sig. (2-tailed)	.034	.847	.063	.535	.091	.569
		N	16	16	16	16	16	16
	The use of images to support text was useful.	Correlation Coefficient	.209	.200	.202	.175	.180	.259
		Sig. (2-tailed)	.437	.458	.453	.517	.504	.334
		N	16	16	16	16	16	16
	There was too much happening at one time with some animations.	Correlation Coefficient	-.655	.774*	-.661	.692	-.619	.886**
		Sig. (2-tailed)	.110	.041	.106	.085	.138	.008
		N	7	7	7	7	7	7
	The animations were too long.	Correlation Coefficient	-.657	.302	-.724	.299	-.487	.365
		Sig. (2-tailed)	.109	.511	.066	.515	.268	.421
		N	7	7	7	7	7	7

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 108

The final analysis of the students' overall perceptions of EDEC once again indicated that those with a deeper tendency were more likely to have a positive perception of the package than those who demonstrated a surface tendency (Table 109). In particular, there was an observable significant relationship between low surface tendency and willingness to recommend EDEC to other students. The analysis of the students' perceptions of the EDEC modules as preparation for the practical labs however demonstrated no trend indicating that perception was independent of approach to learning in this instance.

Comparison of R-SPQ-2F Results and the Students' Overall Perceptions of EDEC

			Deep approach	Surface approach	Deep strategy	Surface strategy	Deep motive	Surface motive
Spearman's rho	Overall, I liked using the system.	Correlation Coefficient	.304	-.077	.311	-.034	.191	-.064
		Sig. (2-tailed)	.253	.778	.241	.901	.479	.815
		N	16	16	16	16	16	16
	I would use this system again in my studying.	Correlation Coefficient	.347	-.468	.287	-.429	.282	-.348
		Sig. (2-tailed)	.189	.067	.280	.097	.291	.187
		N	16	16	16	16	16	16
	I would recommend the system to other students.	Correlation Coefficient	.398	-.590*	.390	-.556*	.255	-.447
		Sig. (2-tailed)	.127	.016	.136	.025	.340	.082
		N	16	16	16	16	16	16
	The EDEC modules prepared me well for the lab sessions.	Correlation Coefficient	-.018	.183	.083	.127	-.194	.222
		Sig. (2-tailed)	.969	.694	.860	.786	.676	.632
		N	7	7	7	7	7	7

*. Correlation is significant at the .05 level (2-tailed).

Table 109

In general, the analyses of approach to learning against overall perceptions of the EDEC package indicated that students with a deep tendency were more likely to be positive in their perceptions of the package than their surface counterparts. In terms of deep/surface motivation, it can be seen that there is a less pronounced difference between the two groups. The results would indicate that hypotheses 1 to 3 would tend to be rejected for approach to learning, learning strategy and learner motivation. This is consistent with the results obtained from the first and second case studies with regard to approach to learning and learning strategy, however the trend which was shown for learner motivation does not strictly conform to the analyses of the first two case studies.

5.11. Individual Student Comments

As well as evaluating the impact of EDEC on the entire sample, there was an opportunity to consider comments made by individual students (see Appendix O) in relation to their learner profile as identified through the CSA and R-SPQ-2F measures. The first of these was student 3 whose comments indicated a goal-orientated approach to EDEC, which is supported by his generally surface profile (Table 110).

> *"I generally found EDEC very time consuming. Time spent reading screen, then taking notes could have been utilised better. Handout sheets with printed notes or screen captures from EDEC would be more useful*

as students could read notes and highlight important points. However the animations were very useful but were either too fast or too slow."

Student 3 - Profile	
Cognitive Style (Wholist /Analytic)	Intermediate
Cognitive Style (Verbaliser/Imager)	Bimodal
Deep/Surface Approach to Learning	Surface
Deep/Surface Learning Strategy	Equal
Deep/Surface Motivation	Surface
Overall, I liked using the system.	Strongly disagree
I would use this system again in my studying.	Strongly disagree
I would recommend the system to other students.	Strongly disagree
The EDEC modules prepared me well for the lab sessions.	No response

Table 110

The student's responses to the perceptions questionnaire clearly indicated that he disliked the EDEC package. Although he acknowledged the usefulness of some of the animated elements, his overall perception of the modules as being 'time-consuming' alluded to his frustration with the method of processing required by EDEC and his need to create his own set of notes.

"Hand-out notes could be more useful."

Student 4, who had a similar profile to that of student 3 (Table 111) also provided an insight into the frustration that he felt in having to take manual notes from the screen.

"EDEC should be of the standard Windows format, common to most packages. More of a Powerpoint slideshow, with all the standard cut and paste facilities. Sometimes too much information on-screen, becomes blazé!"

Student 4 - Profile	
Cognitive Style (Wholist /Analytic)	Intermediate
Cognitive Style (Verbaliser/Imager)	Verbaliser
Deep/Surface Approach to Learning	Surface
Deep/Surface Learning Strategy	Equal
Deep/Surface Motivation	Surface
Overall, I liked using the system.	Disagree
I would use this system again in my studying.	Strongly disagree
I would recommend the system to other students.	Strongly disagree
The EDEC modules prepared me well for the lab sessions.	Neutral

Table 111

His comment also alluded to information processing problems and the potential for skimming over media once the student had become familiar with the format of EDEC.

The comments from student 5 who profiled as a deep learner (Table 112) further alluded to problems with information processing and the need for the initiation of multiple reviews of animated media for conceptual understanding.

> *"Simple with very little in-depth explanations. Material was a good base to start a study into a subject. Some examples required to be run several times before they were fully understood. Would be better if the animation could be paused."*

Student 5 - Profile	
Cognitive Style (Wholist /Analytic)	Wholist
Cognitive Style (Verbaliser/Imager)	Verbaliser
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Overall, I liked using the system.	Disagree
I would use this system again in my studying.	Disagree
I would recommend the system to other students.	Disagree
The EDEC modules prepared me well for the lab sessions.	No response

Table 112

Student 6 was a little less negative in his overall perception of EDEC (neutral) than some of the others and was the only respondent to strongly agree that the EDEC modules had prepared him for the subsequent practical labs (Table 113).

Student 6 - Profile	
Cognitive Style (Wholist /Analytic)	Intermediate
Cognitive Style (Verbaliser/Imager)	Bimodal
Deep/Surface Approach to Learning	Surface
Deep/Surface Learning Strategy	Surface
Deep/Surface Motivation	Surface
Overall, I liked using the system.	Neutral
I would use this system again in my studying.	Strongly disagree
I would recommend the system to other students.	Disagree
The EDEC modules prepared me well for the lab sessions.	Strongly agree

Table 113

His open comments on the EDEC package and his experiences with it were also generally positive. Although he strongly disagreed with the statement *'I would* *use this system again in my studying'*, he qualified this response by saying that *'in its present state'* he would not choose to use it again.

> *"EDEC is a good idea. Just needs more work on it. Developers should consult/interact with users to know how they take to it and use it. They would see what the user finds particularly good and build those into the rest of the programme. If that happened then the 'visual learner' would find it a very useful source of learning material! I'm more of a visual learner."*

His surface approach to learning was supported by a number of statements that he made referring to a number of references to the EDEC work that had been made during previous lectures and the processing of information.

> **Comment 1** - *"Hard to understand lecture references. Meant own research needed."*
>
> **Comment 2** - *"Some parts too textually displayed."*
>
> **Comment 3** - *Too much information on each page – "Definitely, making it more concise would be great!"*

While comments 2 and 3 related specifically to the presentation of media, they also implied a sense of frustration at having to process so much information from EDEC. His preference for lectures from the learning resource questionnaire may be an indication of his surface approach, with the lecturer taking responsibility for critical analysis of content prior to delivery. This was not available through EDEC as the modules' content did not provide a complete match with the assignment outcomes due to its off-the-shelf nature. He also highlighted having difficulty with identifying interactive links within the package as was observed in a number of instances.

> *"Hyperlinks were not obvious, looked more like they were emphasised – colour difference."*

Although student 10 profiled as having a deep tendency in the three R-SPQ-2F scales (Table 114), he was perhaps the most vociferous in his criticism of EDEC which was at odds with the general relationship observed in the previous section.

> *"I'm not EDEC's biggest fan...EDEC was possibly the most uninteresting, boring and useless computer package that I have ever*

used. At the beginning I tried to understand and motivate myself to what was going on, but as I went through the package I just could not see the purpose of it at all.

Student 10 - Profile	
Cognitive Style (Wholist /Analytic)	Intermediate
Cognitive Style (Verbaliser/Imager)	Imager
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Overall, I liked using the system.	Strongly disagree
I would use this system again in my studying.	Strongly disagree
I would recommend the system to other students.	Disagree
The EDEC modules prepared me well for the lab sessions.	Disagree

Table 114

This student expressed a preference for the traditional lecture and note-taking format as expressed in his responses to the learning resource questionnaire and this was evident in another of his comments on lectures and EDEC.

> *"Original way and best. Personally, I feel that it is of use only to lecturers, where they can just take a back seat away from teaching. Some students will possibly prefer this method but the amount of learning they will gain is very debatable. Improvements that could be made is definitely more interaction in the package."*

He also further highlighted the problems that a number of students expressed with animated elements,

> *"If animations too fast, reading screen at same time became difficult."*

Although all of the animations operated at the same frame rate, his observation that they were *'at times too fast, at times too slow'*, may indicate a degree of frustration with the length of some of them.

In general, the more detailed examination of individual student comments demonstrated the lack of a consistent and coherent pattern in relation to cognitive style and approach to learning. While the analysis of the entire sample indicated a number of relationships between the R-SPQ-2F results and perceptions of EDEC, the individual analysis of student comments paint a more complex, albeit generally negative picture with regard to the students' perceptions of the resource. The recurring issue of information processing and in particular students' problems with the processing of animated media did however remain pretty consistent across measures.

5.12. Observation of the EDEC Lab Sessions

An observation log was kept during each of the lab sessions. These were intended to provide qualitative data on the students as they progressed through each module for triangulation with other data during the analysis phase. Each observation episode was carried out for the duration of each session and was time-stamped as individual observations were noted.

The lecturer's expectation was that each student should have completed all six EDEC modules within two to three weeks. He therefore anticipated that they would be required to spend time on EDEC outwith the timetabled lab sessions which lasted for two hours. After a brief introduction to the EDEC interface by the lecturer the students were left to complete all the modules in their own time. This differed from the first two cases studies where each EDEC session was timetabled to cover a discrete module.

The atmosphere within the lab generally appeared relaxed and informal, with a fair degree of peer to peer cooperation evidence between students. The students were able to come and go as they pleased during each session and the lecturer typically entered the lab about an hour into each session where he discussed the EDEC content and the assignment more generally on a one-to one basis with each student. It was indicated to me that they had some prior experience with EDEC during the second year of their degree course.

5.12.1. Observation of Students' Approach to using EDEC

Although each session was intended to last for two hours, none of the students present used the full allocation of time available as was the case during the first two case studies. At the start of the first session the lecturer highlighted the fact than none of the EDEC material would be supplemented with lectures or other resources. He then reinforced his expectation that they should manage their time and take responsibility for their own learning over the course of the entire six weeks that were timetabled for the assignment. He also impressed upon them that from past experience they should expect to '*...have to go over some material more than once*', and should avoid skimming over screen information. He finally stressed the importance of the accompanying workbook to the final assessment of each assignment and encouraged each student to take notes using the workbook. Most of the students spent a little time familiarising themselves with the workbook before commencing with the first EDEC module A number of the them were subsequently observed to be reluctant to use the workbook for note-taking, instead preferring to take separate notes as required. In general, many of the students were observed to have taken a rigorous approach to their note-taking, many of them writing all screen content down verbatim. This observation was corroborated by the course lecturer during the second session. It could be speculated that their criticism of the EDEC package was in part due to their approach to notes which in many cases took the form of merely copying from the screen for later study. The obvious implication here was that many of the students still preferred to read from hardcopy paper than from the screen. It also undermined much of the impact of animated media as they were more intent in copying textual content than processing the conceptual knowledge demonstrated through animation. This was particularly evident by the third session where some students were observed avoiding animated media altogether in favour of textual content. By this stage they had become very tactical in their approach to EDEC and there was evidence of students cooperating in a manner intended to promote as good a grade as possible without the need to fully engage with the modules. Towards the end of the sessions a number of students were observed to have used screen capture facilities within Windows™ for the purposes of printing entire screens resulting in a drop-off in their processing of animated and interactive media.

There was further evidence of this sample of students exploring the structure of EDEC and the navigation system prior to commencement of the modules themselves, however a number of them were observed to have had problems with the help system when they initiated it. This was largely due to their expectation of the help interface which was basic and non-interactive when compared with commercial software help files. There was evidence of this causing frustration among some students during the first module. During this session small groups of students started to engage in discussion about problems they were experiencing with the interface. One student was observed relating his misinterpretation of sections of blue text, which he had assumed were interactive hyperlinks. They were, in fact, blue for emphasis only. There were a number of observed instances of students clicking the mouse cursor over different areas of the screen in search of interactive elements and mis-identifying content as being interactive. There was one very clear instance where a number of students failed to identify a series of interactive pop-up windows that were intended to provide important support text for the current screen, often in the form of programming code. Around half of the students failed to locate these pop-ups before they were highlighted by the lecturer resulting in them having to revisit a number of previous screens to search for these elements.

There was a higher degree of evidence of students engaging feedback loops and revisiting previously viewed content during this case study than the first two. This may in part have been due to the more complex structure of the EDEC material than for the first and second year cohorts. While the students readily initiated multiple reviews of animated elements, it was clear on occasions that some were taking notes while animated elements were in progress. It was most likely also down to the nature of assessment whereby the completed notes or workbooks formed a part of the assessable outcome. The observation of their processing of animated media also indicated that many of the students applied a 'chunking' approach, making multiple reviews of animations until they were comfortable that they had processed them completely. This further highlighted the benefits that would have been achieved if they had been able to stop and start each animation in line with their processing.

The general pattern of use of EDEC differed a little with this particular cohort. with a less linear approach to the modules than was observed over the previous two case studies. It was speculated that this may have been partly due to the lecturer's approach to the learning environment where the students' took responsibility for the completion of the six modules within a period of two to three weeks. Because the expectation was not to simply complete a single module during each session, the students were more likely to work at their own pace and switch between modules as required. The direct relationship between the modules and the formative report structure of the assessable outcome would no doubt have contributed to the students' approach in this case. This also led to the students being more generally 'on-task' than was evident during the second case study in particular, where the modules were more intended for knowledge acquisition in support of a subsequent practical task. When this issue was discussed with the course lecturer he intimated that the embedding of the EDEC modules and their outcomes in the assessable outcome was intentional so as to force the students to integrate the knowledge gained through EDEC within the written assignment.

Since the EDEC package was intended to be used alongside a commercial simulator package it was important that the students could move seamlessly between the two software environments when required. The nature of the learning environment allowed the simultaneous use of the simulator package and EDEC, although a number of students experienced difficulty with their simultaneous use. When this was raised with the course lecturer he regarded any problems as being '*file management*' issues, although he did acknowledge later that there were known problems which related largely to the design of EDEC. There was a fair degree of cooperation among the students regarding the technicalities of running both software packages simultaneously, although this discussion sometimes detracted from the students' ability to simply complete the modules leading to a degree of frustration.

The students underwent a brief orientation phase when they started to use the simulator package and moved from knowledge acquisition to project work. At first this led to an observable de-motivation among the class as they adjusted from taking notes to critical analysis of them. The learning environment did however promote the review of EDEC modules alongside current tasks, although some of the students preferred to work between paper notes and the simulator package. The lecturer commented to the students that he expected them to be able to demonstrate the development of programming code beyond the scope of that which was covered by the EDEC modules. This was prompted by the initial tendency for the students to simply repeat code that had been delivered through EDEC and which had been taken down as notes.

Although each EDEC session was timetabled to last for two hours, it can be seen from the observation notes (Appendix N) that the students typically stayed in the lab as a group for around half of the allocated time. Through discussion with the course lecturer, it became apparent that common practice was for students to take a break at around the half-way point in sessions and it was common for them to miss the second half of the session. Since it was the responsibility of the student to ensure that he or she had completed all of the work required for the assessed assignment, the lecturer did not enforce a strict policy with regard to student attendance for the two hours of each session.

5.13. Interview with Course Lecturer

At the end of the three EDEC sessions an interview was conducted with the course lecturer. This was done to gain further insight into the ethos of the course. the use of the EDEC modules and the wider consideration of their use in the context of students' learning. The interview lasted for approximately fifty minutes and followed a semi-structured format, which was agreed with the interviewee prior to commencement (see Appendix P). The interview was recorded using a digital voice recorder.

I began by asking the lecturer to discuss the historical context for his choice of EDEC as a learning resource. He highlighted his participation in an electronic discussion forum which was set up to inform the development of the EDEC materials as providing the basis for his ultimate adoption of it. He said that he had regarded himself as a *'provider of ideas'* to the forum and therefore implied a sense of implicit ownership of the EDEC package and its development.

He had evaluated a number of EDEC modules that had been developed by the different consortium members and he considered that they had provided *'some* *very good resources'* although he also indicated that this was not the case for all EDEC modules.

> *"...very distinct differences in style and presentation; and I don't just mean that from the user interface point of view, because that wasn't really too much of a problem; but the academic style of presentation. The way in which learning materials, or learning information was presented for students to use; it's very different from the different elements or parts of the consortium. Sometimes some of the modules of the material, they're not really interactive at all. They don't use many examples, they don't use many applications. The VHDL modules do these things. There is some interactivity, there are some pseudo simulations, not fully blown simulations but pseudo simulations, more animations really, which is useful."*

When he was asked to discuss his selection criteria for the adoption of EDEC modules he said they were based on a combination of subject content and pedagogical style of delivery. He regarded the VHDL modules as being the core resource for the unit of work, leading directly to an assessable outcome, which would ultimately influence their degree classification. He was keen to stress however that he expected the students would have to undertake a degree of independent learning through other resources in support of their learning.

> *There are examples of VHDL code actually being explained, for students to use; and it is assumed – very importantly, it is assumed that the students will be doing other types of work on VHDL. For example, they'll be learning something about the syntax of VHDL through book reading or some other source. It's assumed that they will be using a simulator in order to simulate some of the things that they're learning about and even simulating their own code that they're working on based on their learning experience."*

The discussion moved on to his pedagogical approach to the use of EDEC and its role within the learning environment where he stated his aim was to '*integrate computer based learning materials into other type of learning, because for a long number of years now, I firmly believe that computer based learning cannot replace everything in the student learning experience*'. He did however allude to the difficulties that can arise from the use of generic learning material such as EDEC.

"Not only is integration the name of the game, but also being able to select elements of computer assisted or computer based learning or Internet or Web material or whatever. Lifting sections, segments, you know, having the granularity in the material to do that. Now there is a limit to which you can do that with EDEC because really once you pick up a module for a student to use, then they're really going to have to use that module. But ultimately, I think that to have some finer granularity in there would be useful as well. So they could have what would really be sub-EDEC modules on a particular topic that I would then be able to put together to construct what I think is appropriate."

It was interesting to note the different perspectives of the lecturer and the students in their perceptions of the learning environment. The students' perceived view tended towards the idea that the lecturer had selected a particular resource for the unit of work (EDEC) and this would therefore provide them with the knowledge required to complete the assignment. The lecturer on the other hand perceived EDEC as a component of a wider learning environment which demanded a degree of independent learning from the students to gain the knowledge required to complete the assignment. This conflict of perception was evident in two comments; one from the lecturer and one from a student.

Lecturer comment: *"The implementation of EDEC within any course should not be viewed as a quick fix, which frees up lecturers' time."*

Student comment: *"Personally, I feel that it is of use only to lecturers, where they can just take a back seat away from teaching."*

Although he wished to promote the flexibility offered by Web-based delivery, his experience of setting the software up for delivery indicated his encountering problems.

"...it's not straightforward to make the material available for external Internet access."

He highlighted the need for specialist server support for the software and technical support required to host the software which was not always available. Although his own evidence suggested that almost all students had accessed EDEC from home at some time, he acknowledged that much of the university's server maintenance took place over weekends which would limit their access to EDEC at a time where he would have encouraged independent learning. This was a particularly important issue raised by part-time students who worked during week days and wished to access the material at weekends. He also indicated that he had been made aware of problems that some students had encountered in downloading a plug-in required from Macromedia™ to run the EDEC software.

> *"The major issue was a purely technical issue, in the sense that the plug-in that was required is one of a number of plug-ins that are available from the Macromedia download site and virtually everybody who downloaded the plug-in discovered it was the wrong one."*

When the discussion moved to the EDEC interface, he gave an interesting insight into the longevity of many software packages, including EDEC.

> *"Even five years ago...the students' expectation of CBL materials and computer-centred information in general was limited. The notion of actually learning from a computer was very new when EDEC started. When students sat down initially with EDEC, they were mesmerised by the possibility that you could go through a computer based information resource and learn something from it; and read information and every few screens see an animation, and this was quite mesmerising; It was revolutionary. Sit a similar cohort down at the same software now and after a few minutes they're wondering what this is; it's dated. It has not been evolving at the pace which is necessary to make it stay relevant."*

I asked him what changes he would make to EDEC based on his needs and perceptions of the package in its present form. His response concurred with the views expressed by a number of the students.

> *"In particular, the development of simulations is very, very much needed and the notion of interactivity...has got to be developed quite extensively*

and quite rapidly. That's the key thing; the interactivity. To get the interaction between the material, the resources and the student, and that is becoming quite noticeably lacking."

Since he used the EDEC package during all four years of his degree programme I asked whether he had observed any difference in the students' perceptions of EDEC based on their year of study. His response indicated a change in perception which was based on the students' year of study and maturity as a learner.

I've been finding senior undergraduates (3rd and 4th year students), in the last year certainly...are becoming increasingly critical of EDEC because it is not always meeting the kind of expectations that they might expect from an electronically based, computer based learning experience. Because they've got experience of other things now. Junior undergraduates don't have that sophistication; they don't have such a critical view yet."

His further elaboration highlighted the different stages of learning observed by Perry, with students moving through phases from 'dualistic' to 'commitment', and becoming more discerning independent learners.

"By the time students get to later years, they are much more sophisticated and they are much less tolerant of learning strategies being suggested, or indeed imposed on them that are not productive."

When he was asked to discuss the students' completion of workbooks in support of their use of EDEC he indicated that the development of the workbooks by the EDEC consortium seemed to have been an 'afterthought' based on feedback from users. He therefore developed his own workbook which was a hybrid of the EDEC material and his own. The workbooks were issued to all students at the start of the unit of work and contributed to the assessment of the assignment which was the outcome of this part of the course. The students were therefore expected to complete the workbook with their own notes as they progressed through the modules. When the discussion was broadened to some of the students' perceptions of EDEC as no more than an electronic workbook he responded, *"At the moment, one of the great cries from the students that are using EDEC is: Why don't you just give us it in a set of notes? Why is it not just in a book? What's the point of this? We can read the notes on the train when we're coming in; there's no point in this. So it really has to move away very quickly from the electronic textbook model."*

He highlighted the need for EDEC to extend the use of media such as animation and simulation and away from excessive textual delivery akin to a traditional textbook to demonstrate the benefits of the learning technology over static means of delivery, although he acknowledged the need for a balanced approach to resourcing overall.

"It's my perception that it's dawning on more and more people: students, academics alike, that we're never going to replace textbooks, we're never going to replace printed material in the learning environment. It's this thing of not trying to do things with electronic resources that can be done better some other way."

The opportunity to reflect on his use of EDEC through the interview appeared to somewhat change his perception of the package. When he asked to consider his future use of EDEC, he was rather negative in his response.

"Be under no illusion that whenever something better than EDEC appears, if something better than EDEC appears, people are going to migrate onto it. If EDEC doesn't change, if it doesn't evolve, then they will be even more highly critical and will possibly resist EDEC, if it doesn't change..."

5.14. Discussion

The very different situation in which this case study was carried out (final year undergraduates within a month of completion of their degree) when compared with the other two gave a different perspective on the use of the EDEC materials. This was particularly evident in their perceptions of the EDEC package which were typically more negative. The fact that the students in this sample had had four years in the institution where they were undertaking their degree also contributed to the dynamics of the cohort as well as the quality of the interaction between themselves and the course lecturer. This particular group of students exhibited a much greater degree of independent learning than the previous two cohorts. This may be attributable to their maturity as learners and also the design of the learning environment which was intended to make the students take responsibility for their own learning and was supported by the course lecturer through a number of external links which were cited on the course web-site and were related to the EDEC materials. This no doubt necessitated more complex approaches to EDEC, both in the sense of working towards specific learning outcomes and through the accompaniment of independently sourced of learning materials. This may partly explain the low reliance on the EDEC materials when compared with the other two student samples. The nature of the assigned task also appeared to contribute to the students' approach to using EDEC, although there was evidence from a number of measures to suggest that they regarded the modules as little more than electronic textbooks.

Although the sample size was small, the analysis of data relating to student confidence gave no indication of a relationship between either cognitive style or approach to learning and confidence. This also proved to be the case when cognitive style was tested against the students' perceptions of EDEC and was consistent with the results obtained during the second case study. The positive relationship observed between a number of perceptions variables and students with a deep learning tendency was also relatively consistent with the indications observed during case study two.

Chapter Six

Students' Use of EDEC - Case Study Four

6. Introduction

This chapter will consider the students' general approach to using the EDEC package and their compliance with four procedural models that were developed to evaluate their processing behaviour in relation to different screen types. Of the four case studies undertaken, this one was intended to provide a more qualitative insight into how students approached their use of the package. The key methodologies employed during this case study consisted of a combination of individual student think-aloud, which was carried out during their use of the package followed by post-intervention interviews. The sample consisted of seven third year undergraduate students from a university in the west of Scotland.

In order to be consistent with the other three case studies a learning profile was developed for each student through the administration of the Cognitive Styles Analysis Test (CSA) and the Revised Study Process Questionnaire (R-SPQ-2F). Other methods used in gathering data included observation and questionnaire. A full breakdown of the measures used during the case study is shown in Table 115.

Area of Investigation	Methodologies
Cognitive styles assessment	Cognitive Styles Analysis Test (CSA)
Student learning	Think-aloud Protocol Post-EDEC interview Pre/Post Test Quiz Observation Log
Learning strategies assessment	Think-aloud Protocol Revised Study Process Questionnaire (R-SPQ-2F)
Student motivation	Think-aloud Protocol Revised Study Process Questionnaire (R-SPQ-2F)
Student perceptions of the Web-based learning material	Questionnaire Post-EDEC interview
Learning resource use	Learning Resource Questionnaire

Table 115

6.1. The EDEC Module

The material covered by the students during the evaluation consisted of a single EDEC module called "Number Systems". It was broken into the following theoretical sections:

1.1 Introduction – Using the Package

1.2 Introduction – Binary Numbers

1.3 Introduction – Hexadecimal Numbers

2.1 Negative Numbers – Sign and Magnitude

2.2 Negative Numbers – Complementary Numbers

3.1 Multiplication and Division – Binary

The structure of the module was such that students were quickly expected to become familiar with its format. Typically this entailed the delivery of introductory theory relating to the current topic followed by a demonstration calculation and finally one or more screens where students were expected to input answers to on-screen calculation questions. This structure was repeated for each of the topics covered by the module.

6.2. The Learning Environment

A more controlled learning environment was required for this case study due to the logistical and technological requirements of data gathering. Each think-aloud was carried out at the same computer workstation. Data was gathered through the use of a webcam, a voice recorder and screen capture software, which was used to record all on-screen activity. I was seated behind each student with a clear view of the computer screen so that observational notes could be taken. Each item of equipment was positioned as unobtrusively as possible so as not to influence the students' interaction with the EDEC package. Once the purpose of the research and the equipment that was to be used were discussed with the student, he or she was asked to begin when they were ready.

6.3. Think-aloud Sessions

Each think-aloud session was scheduled to last for up to three hours in order to be consistent with the timetabled sessions in the other case studies. It was however anticipated that no student would take the full three hours to complete the module as was the case during the timetabled sessions. Table 116 shows the total time spent on the module by each student and the mean time for the sample.

Total Time Spent on Number Systems Module

		Total time spent on module in seconds
Student 1		1937
Student 2		3780
Student 3		4047
Student 4		3340
Student 5		2056
Student 6		4646
Student 7		3443
Total	N	7
	Mean	3321.29
	Std. Deviation	1002.02

Table 116

The deviation from the mean time demonstrates that the time to complete the module varied greatly from student to student. In particular, students 1 and 5 spent considerably less time on it than the others (58% and 62% of the mean time respectively). At the other end of the spectrum, student 7 spent more time than any other student on the module at 40% above the mean time. A further detailed analysis of the time spent on different screens conforming to the four procedural models can be found in section 6.13 of this chapter.

While none of the students had prior knowledge of the specific topics covered by the module a degree of prior knowledge of binary and hexadecimal systems became apparent during the post-EDEC interviews. After a brief introduction to the session and discussion of my role as the researcher, students were expected to proceed through the module on a self-study basis.

The same procedure was followed during each of the think-aloud sessions. Students were first asked to acquaint themselves with the environment and the computer that would be used during the session. They were then asked to wear a headset microphone for the purposes of recording their verbalisations. I then briefly explained the concept of think-aloud, the resources that would be used to record their verbalisations and their interactions with the package, and my role as observer. Once the procedure had been fully explained to each student, they were asked to give their consent to take part in the study. Each student was also asked during post-EDEC interviews if the process of thinking aloud had any bearing on their ability to use the package. None of them considered that the procedure had hindered their ability to work through the package, although one student admitted to a degree of embarrassment at the start of her verbalising.

6.4. Observation of Think-aloud Sessions

An observation log was completed during each student's EDEC session in order to take notes on students' use of the package and the cognitive processes that they followed in progressing through the Number Systems module. A pro-forma document was developed to log observational data as well as general information that would allow me to anonymously identify the student, the particular screen that the observations pertained to and a timeline (see Appendix Q). The observation log was intended to provide corroborating support for issues identified by each student as they verbalised during their use of EDEC and also during the debrief interviews. These three qualitative measures would also be triangulated with quantitative data gathered through questionnaire and pre/post-tests.

6.5. Post-intervention De-briefing Interviews

A post-EDEC interview was carried out with each participating student at the end of their EDEC session. This was intended to provide a platform for discussion on their perceptions of the package as a learning resource, issues that they encountered in their use of the package as well as to validate the observational data. Each interview was recorded using a digital voice recorder for ease of transcription and data management (see note at end of this chapter).

6.6. The Development of Procedural Models

Four procedural models were developed to depict idealised approaches to students' processing behaviour as they moved through each screen in the Number Systems module. These were derived from the consideration of type of media, cognitive processing requirements (problem solving activity) and any anticipated user interaction for each screen type. The structure of each model necessitated a different number of processing phases depending on the contents and user requirements for each screen type. Table 117 provides a breakdown of the procedural models and typical interaction requirements for each screen type.

Model No.	Processing Phases	Description
1	Read text – orientate – reflect	Screens where physical interaction between the subject and the screen was not anticipated beyond the reading of text and/or review of static images.
2	Read text – orientate – process animation – reflect	Screens where subjects were expected to review a concept through the reading of text and review of animation.
3	Read text – orientate – analyse concept – test concept – reflect	Screens where subjects were expected to review a concept and then interact with the package to consolidate their understanding of the concept.
4	Read text – orientate – analyse concept – calculate - test concept - reflect	Screens where subjects were expected to carry out a calculation and input an answer directly to the package.

Table 117

In considering the delivery of different types of media it was determined that the processing requirements for animation and text (see section 2.1.1) necessitated the development of discrete models for information delivered via both forms of media (models 1 and 2). Similarly, the different cognitive requirements of multiple choice and drag and drop type questions against open calculation questions led to the development of discrete models for each type of screen (models 3 and 4). This manifested itself during the sessions through observable differences in the nature of students' approach to the analysis and testing phases outlined in Table 117. Since model 3 screens typically contained multiple choice or drag and drop type questions there was scope for students` to take a trial and error approach, in order to achieve a correct answer. This had implications for their approach to the procedural model that would not have been anticipated for model 4 screens that relied on open calculation type questions.

The inclusion of a '*toolbox*' facility in model 4 screens permitted a more complex approach to the processing phases than for model 3 questions. The tables and calculators inside the toolbox could have been used to simply calculate the correct answer for input to the system before moving on. It was however observed to have been used more generally as a prompt for the initiation of a return loop or alternatively as a reflective tool. One student in particular (Student

2) was observed on a number of occasions using the toolbox to arrive at the correct answer and then work backwards to gain an understanding of the concept. It should be noted that in each case, where the toolbox was made available on screen (see Figure 31, p.241), users were explicitly requested via an on-screen message not to use the toolbox *'if possible'*.

It was expected that there would be a degree of concurrent activity during students' processing of information where two phases were carried out at the same time. An example of this would be the merging of the 'analyse concept' and 'calculate' phases during the processing of model 4 screens. It was also anticipated that the 'process animation' phase in model 2 screens may include a degree of conceptual analysis.

As well as proceeding through the predicted processing phases it was anticipated that one or more return loops may have been initiated by students as they progressed through each of the screens. These were not included within the procedural models, as they were expected to be particular to the individual student and therefore not applicable to the general models outlined. A typical example of students' initiation of return loops came during their use of the on-screen tables and calculators embedded in a 'toolbox' facility available to support open calculation questions (see Figures 31 and 32 in sections 6.10.1.4.1 and 6.10.1.4.2).

The students' use of resources was also analysed in relation to their interactions with individual screens and the procedural models. The resources available to students included pen and paper, an electronic calculator and a number of embedded calculators within some of the EDEC screens. Individual students' approach to resource use will be discussed later in this chapter.

Table 118 provides a breakdown of the individual screens that made up the EDEC Number Systems module and their applicable procedural model as well as a brief description of the type of media content within each screen.

Screen Number	Procedural Model	Description of Media and Interaction Required
1.1.2	1	Text only
1.1.3	1	Text only
1.1.4	3	Text + drag and drop question
1.2.1	2	Text + button + animation
1.2.2	3	Text + buttons + calculation
1.2.3	3	Drag and drop question + multiple choice concept question
1.2.4	4	Text + data input calculation
1.2.5	2	Text + hidden text + button + animation
1.2.6	4	Text + data input calculation + toolbox
1.2.7	2	Text + button + animation
1.2.8	4	Text + data input calculation + toolbox
1.3.1	2	Text + button + animation
1.3.2	3	Text + button + drag and drop question
1.3.3	3	3 multiple choice concept questions
1.3.4	2	Text + button + animation
1.3.5	4	Text + data input calculation + toolbox
2.1.2	3	Text + buttons + calculation
2.2.1	2	Text + button + animation
2.2.2	2	Text + button + animation + button + display answer
2.2.3	2	Text + button + animation
2.2.4	2	Text + button + animation
2.2.5	4	Text + data input calculation + toolbox
2.2.6	3	Text + buttons + calculation
2.2.7	2	Text + button + animation
2.2.8	2	Text + button + animation
2.2.9	4	Text + data input calculation + toolbox
3.1.2	2	Text + button + animation + button + animation
3.1.3	2	Text + button + animation
3.1.4	4	Text + data input calculation + toolbox
3.1.5	2	Text + button + animation + button + animation

Table 118

The following sections will first discuss the students' general perceptions of the EDEC package and resource preferences followed by an evaluation of each student's individual approach to using the package.

6.7. Student Perceptions of EDEC

In order to gain a quantitative insight into the students' perceptions of the EDEC package, a questionnaire was administered to the sample after they had completed the module (Appendix A). Its content was identical to the one administered during each of the earlier case studies. The questions were intended to gather data that was specific to the use of the EDEC material as well as more general perception data on the use of computers and the Web as a means of learning. The following sections (6.7.1 to 6.7.7) will review the results from the different sections of the questionnaire.

6.7.1. Learnability of EDEC Interface

Each student was asked to respond to a number of statements relating to their general use of the package (Table 119). From the table it can be seen that they were generally comfortable with the package in terms of ease of use, with the only area of concern being the lack of help available when they became confused.

Results of Learnability of EDEC Interface - Frequency of Responses (n=7)					
Learnability	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I could follow the instructions clearly.	0	0	2	4	1
I quickly became familiar with the system.	0	0	4	3	0
Parts of the system were difficult to use.	0	4	3	0	0
The instructions on screen were sufficient when needed.	0	0	0	6	1
The system helped me if I got confused.	1	1	2	3	0

Table 119

6.7.2. Navigability of EDEC Interface

Responses to statements relating to the navigability of the interface and the general structure of the system again produced predominantly positive responses. It can be seen from Table 120 that the students were generally clear on how to move through the system and on how it was structured.

Results of navigability of EDEC interface - Frequency of Responses (n=7)					
Navigability	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
It was clear to me where I was in the system.	0	1	1	3	2
It was clear how to move through the system.	0	0	2	2	3
I think that the system is generally well structured.	0	0	2	3	2

Table 120

It was however noted during the observation of students and through screen capture that they typically chose not to explore the functionality of the package as outlined on screen 1.1.2 (Figure 20). Of the seven navigation and function buttons available to users, only the two buttons that allowed the students to move forward or backward one page were used during all the sessions.

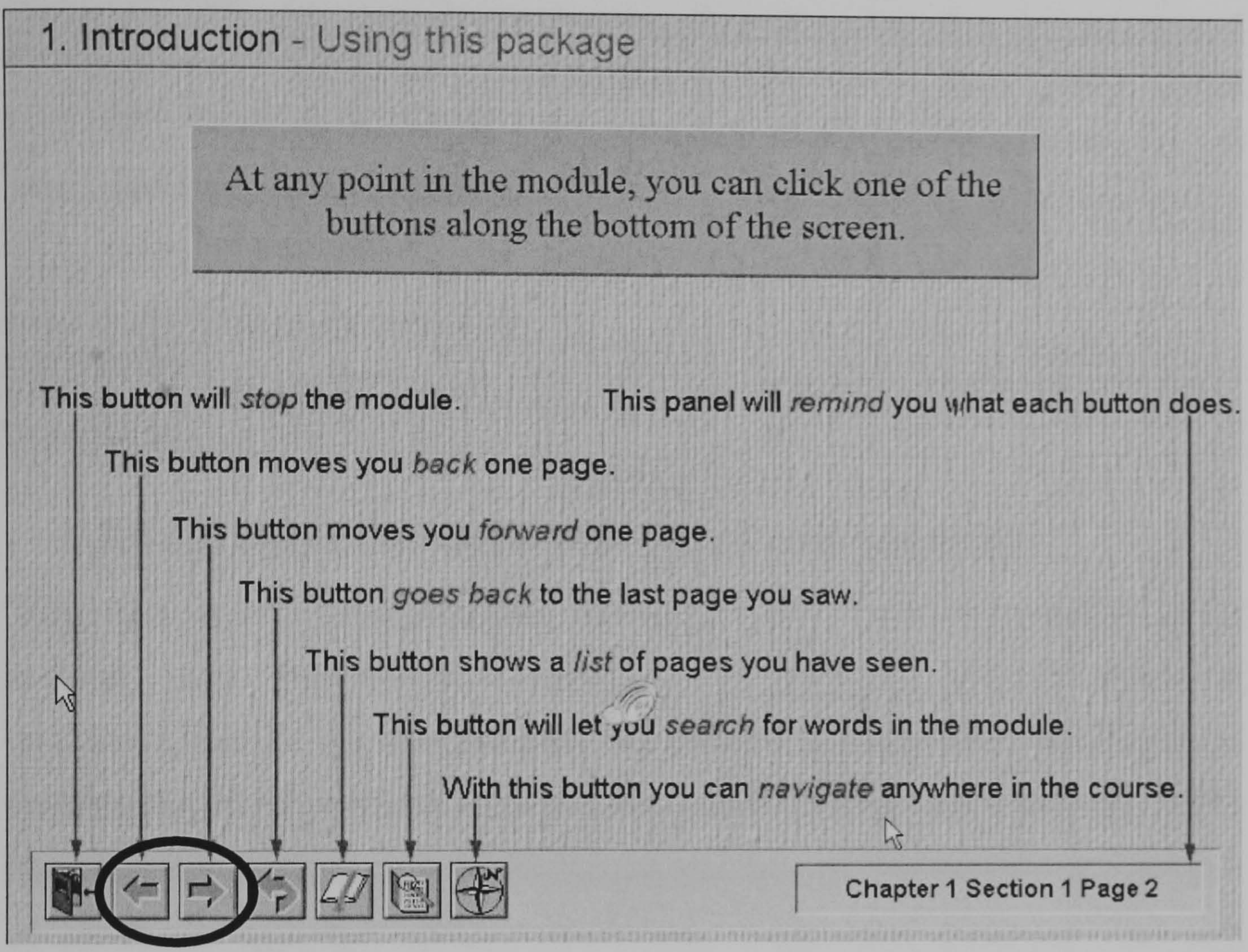


Figure 20

6.7.3. Quality of the EDEC Interface

When asked to give their perceptions on the quality of the EDEC interface (Table 121), the responses were again generally positive towards the presentation of information, the use of language and the user-interface. It can however be seen from the table that less positive responses were given to the statements *'I got what I wanted from the system quickly'* and *'There was too much information on each page for me to remember'*. In each of these cases the responses were predominantly neutral (4 out of 7 cases). The neutral responses to the second of these statements may relate to some students' problems with processing information into short-term memory from one screen for later retrieval during another, as was observed at times during some students' use of the package.

Results of Quality of EDEC Interface - Frequency of Responses (n=7)					
Quality	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I found that the information was presented consistently.	0	0	0	6	1
It was obvious how to use the icons (buttons).	0	0	1	4	2
The language was clear.	0	0	1	4	2
I could easily read from the screen.	0	0	0	4	3
The screen colour did not interfere with my reading.	0	0	0	5	2
I got what I wanted from the system quickly.	1	0	4	2	0
Overall, the system had an attractive presentation.	0	1	2	2	2
There was too much information on each page for me to remember.	0	1	4	1	1
There was too much information which I didn't need to know.	1	4	2	0	0

Table 121

6.7.4. Graphic, Animated and Interactive Elements

While the students were generally comfortable with the use of graphics in the package, three respondents indicated having difficulty with the speed of animations and all seven respondents agreed that it would have been useful if they had the ability to start and stop animations where required (Table 122). Both observational evidence and student verbal protocols confirmed that on a number of occasions, animated elements were seen to run away from the user with obvious implications for their processing ability and subsequent recall. This issue will be explored more fully during the discussion on students' individual behaviour and their approach to model 2 screens (section 6.10.1.2).

Evaluation of Graphic, Animated and Interactive Elements - Frequency of Responses (n=7)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I thought that the graphics were clear and helpful.	0	0	1	4	2
I thought that the interactive elements were difficult to find.	1	4	2	0	0
I found the animated elements too fast.	1	3	0	1	2
I felt that the animated elements would have been better if I could control speed and stop/start.	0	0	0	2	5
The use of images to support text was useful.	0	0	4	2	1

Table 122

6.7.5. Students' Overall Perceptions of EDEC

When asked for their overall impression of the EDEC system (Table 123), responses were more varied with three respondents indicating that they hadn't enjoyed using the package against two who did (two others responded neutrally). Although some students didn't enjoy using the package, they were willing to recommend it to other students. This finding was raised during a number of post-EDEC interviews where the students concerned indicated that they were able to differentiate between their own perceptions of the package and its suitability to them as learners against its suitability to others. This indicated that their problem was not necessarily with the quality of the package per se, but was related to their individual learning style and resource preferences.

Overall Student Perceptions of the EDEC System - Frequency of Responses (n=7)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Overall, I liked using the system.	2	1	2	2	0
I would use this system again in my studying.	1	1	2	3	0
I would recommend the system to other students.	0	1	2	4	0

Table 123

The responses to the questionnaire indicated that the students were generally positive towards in their perception of the EDEC material. They identified no real problems with navigating through the system and found it well structured, although the responses relating to information processing indicated that some students might have had difficulty in processing information for later retrieval.

6.7.6. Students' Use of Computers and the Internet

In order to broaden the context of the evaluation from EDEC-specific to the consideration of the students' more general use of computers and the Internet, a number of supplementary questions were asked towards the end of the questionnaire. These were intended to gain an insight into the importance of the computer and the Internet to the students' studies, as well as evaluating their perceptions of learning through a computer more generally.

It can be seen from Table 124 that computer use and the Internet were considered to be vital components of student activity and learning with 100% of respondents indicating that they used a computer most days and six out of seven using the Internet most days also. The students were however more equivocal in their views as to whether they liked to learn using computer packages with an even split between those who liked and disliked learning with computer packages.

Computer and Internet Perceptions - Frequency of Responses (n=7)					
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I like to learn using computer packages.	1	1	3	1	1
The Internet is very useful to my learning.	0	0	1	4	2
	Less than once a month	**Around once a week**	**3 or 4 time a week**	**Most days**	**Never used one**
How often do you use a computer?	0	0	0	7	0
How often do you use the Internet?	0	0	1	6	0

Table 124

6.7.7. Learning Resource Questionnaire

The students' resource preferences were evaluated at the end of each session through the Learning Resource Questionnaire. The questionnaire asked them to rate how useful a range of resources were to their learning. The results indicated that they valued a wide range of resources and interactions in their learning. The usefulness of EDEC itself was not explored through the questionnaire for this particular case study as students' use of the package in this instance was not in the context of their wider learning, as was the case in each of the other three case studies. The results of the questionnaire therefore refer to respondents' learning preferences in general. The results (Table 125) particularly highlighted the importance of what could be called traditional resources such as textbooks, peer to peer and peer to tutor interaction to the students in support of their learning, a factor which was further highlighted during the post-EDEC interviews.

Usefulness of Resources - Frequency of Responses (n=7)					
	Useless	Not very useful	Useful	Vital	Not sure
Lectures	0	0	3	4	0
Textbook(s)	0	0	4	3	0
Own notes from lectures/labs	0	0	4	3	0
Borrowed notes from someone else	1	3	3	0	0
Discussions with tutor/lecturer	0	0	4	3	0
Discussions with other students	0	0	4	3	0
Other resources	0	1	2	4	0

Table 125

6.8. Pre/Post Test Quiz

A pre/post test quiz which was made up of ten multiple choice questions derived from the content of the Number Systems module was administered to all students before and after the intervention (see Appendix G). The questions for the quiz were selected on the basis that they required different processing methods from the students due to the use and delivery of media and that they reflected the range of topics covered by the module. The quiz was identical in content to that delivered as part of the data collection for case study number two.

Table 126 shows a comparative breakdown of the students' responses to the ten questions covered by the pre and post-test. It can be seen from the results that they were typically more comfortable with questions from the binary section of the module during the pre-test than the hexadecimal and complementary numbers sections.

Breakdown of Pre-test/Post-test Quiz Scores (sample = 7)

	incorrect	correct	don't know
Pre-test Q.1 (Decimal number system)		7	
Post-test Q.1(Decimal number system)		7	
Pre-test Q.2 (Binary number system)	1	5	1
Post-test Q.2 (Binary number system)	2	5	
Pre-test Q.3 (Binary number system)	1	2	4
Post-test Q.3 (Binary number system)	1	6	
Pre-test Q.4 (Binary number system)	2	2	3
Post-test Q.4 (Binary number system)		4	3
Pre-test Q.5 (Hexadecimal number system)	1	2	4
Post-test Q.5 (Hexadecimal number system)		7	
Pre-test Q.6 (Hexadecimal number system)			7
Post-test Q.6 (Hexadecimal number system)	2	1	4
Pre-test Q.7 (Hexadecimal number system)	3	1	3
Post-test Q.7 (Hexadecimal number system)	1	6	
Pre-test Q.8 (Complementary numbers)			7
Post-test Q.8 (Complementary numbers)	3	3	1
Pre-test Q.9 (Complementary numbers)	2		5
Post-test Q.9 (Complementary numbers)	2	4	1
Pre-test Q.10 (Hexadecimal number system)	2		5
Post-test Q.10 (Hexadecimal number system)		5	2

Table 126

A degree of prior knowledge of the binary number system would no doubt have contributed to their better results in these questions. The analysis of pre and post-test results demonstrated the package's effectiveness in raising attainment, with each student showing a positive differential in the number of correct answers achieved between the pre and post-tests (Table 127).

Pre/Post-Test Quiz Correct Answer Differential	
Student 1	5
Student 2	4
Student 3	4
Student 4	2
Student 5	3
Student 6	6
Student 7	5

Table 127

In order to determine whether there was any relationship between cognitive style and the students' performance in the pre and post-tests data from the cognitive styles dimensions covered by Riding's Cognitive Styles Analysis test (wholist/analytic and verbaliser/imager) were compared with students' differential score (Tables 128 and 129).

Comparison of Pre/Post-test Quiz Score Differential and Wholist/Analytic Style Dimension

Count

		Wholist/Analytic Style	
		Wholist	Analytic
Test 1 Differential	2	1	
	3	1	
	4		2
	5		2
	6	1	

Table 128

Comparison of Pre/Post-test Quiz Score Differential and Vrbaliser/Imager Style Dimension

Count

		Verbaliser/Imager Style		
		Verbaliser	Bimodal	Imager
Test 1 Differential	2	1		
	3	1		
	4		1	1
	5		1	1
	6	1		

Table 129

The tables tended to indicate that analytic students performed better than their wholist counterparts, with the exception of one wholist student whose differential score was the best of the sample. Similarly bimodal and imager students typically performed better than their verbaliser counterparts with the same exception. The fact that student 6 who gained the highest differential score (Table 127) spent considerably more time on the module than any other student may in part be responsible for this anomalous finding, although it should be noted that no evidence of a relationship between either cognitive styles dimensions and pre/post test quiz performance was found for the same quiz administered to a larger sample during case study two.

6.9. Individual Student Profiles and Behaviour

Each student's behaviour during their use of the EDEC package was evaluated through a combination of observation, think-aloud and screen capture. These methods permitted triangulated analysis of behaviour at individual screen level during each student's time on the module. These data were further validated through the individual post-EDEC interviews. This section will discuss each student's approach to using the EDEC package and relate their behaviour and perceptions to their pre-determined learning profile, which was developed using Riding's Cognitive Styles Analysis Test (CSA) and Biggs and Kember's Revised Study Process Questionnaire (R-SPQ-2F).

6.9.1. Student 1

Student 1 was a male in his forties. Details of his learner profile and a summary of his general perceptions of the package can be seen in Table 130. The table also shows the total time spent on the module by the student.

Student Profile	
Cognitive Style (Wholist /Analytic)	Analytic
Cognitive Style (Verbaliser/Imager)	Imager
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Pre-test Quiz Score	4
Post-test Quiz Score	9
Overall, I liked using the system.	Agree
I would use this system again in my studying.	Agree
I would recommend the system to other students.	Agree
Total spent on EDEC package	32min. 18sec.

Table 130

This particular student took considerably less time to complete the package than any other student (58% of the mean time spent for the sample). His pattern of behaviour during his time on the module could be characterised as being very linear, with little evidence of reflective behaviour, note taking or initiation of return loops in support of his learning. Although the Revised Study Process Questionnaire (R-SPQ-2F) profiled him as a deep learner in all categories (approach, strategy and motivation), the analysis of his verbal protocol indicated a more surface approach to his use of the package as will be seen in the analyses of his processing of different screen types. His verbalising during the think-aloud coupled with observational data strongly indicated a very goal-orientated approach to his completion of the module, which was centred on his extrinsic motivation to get to the end of the module. These observations tend to contradict his profile via the R-SPQ-2F.

The student experienced a number of problems with the package as he progressed through it, the most serious of which was his complete failure to validate any of the answers that he input to the system. This was because he was unaware that he would receive feedback from the software by hitting the enter/return key on the keyboard after inputting an answer. This issue was raised with him during the post-EDEC interview:

> **Researcher:** *"You missed the fact that you could hit the return key to check your answers."*
>
> **Student 1:** *"Oh, right."*
>
> **Researcher**: *"Were you comfortable with the fact that you weren't receiving feedback because you hadn't picked up on the return key? Would it be fair of me to assume that you were happy that you had the correct answer on each occasion before you moved on?"*
>
> **Student 1:** *"In most cases, yes."*

Screen capture data confirmed that he had, in fact, got four correct answers out of a possible seven questions covered by procedural model 4 screens. Three of these correct answers were achieved during the binary section of the module. His approach to tackling these questions, such as addition and subtraction was to convert from binary to decimal before manipulation, although he struggled with later questions that required a more complex method of processing and manipulation, such as the question on screen 2.2.5 which required manipulation using ten's complement.

His approach was confirmed during the post-EDEC interview, when asked if he'd have found it useful to have been able to check his answers:

> **Researcher:** *"Do you think that you would have found it useful to have been able to check your answers?"*
>
> **Student 1:** *"I would have, maybe to clarify, check my answer to make sure it was right, but with binary I always convert back and forward anyway. I don't know if you noticed I was doing that quite a lot."*

Other instances of problems with the user-interface could typically be attributed to skimming over text instructions, where he used interactive elements incorrectly such as drag and drop, where he was observed to click on answer options instead of dragging them to their appropriate on-screen position, even though explicit instructions were present on-screen.

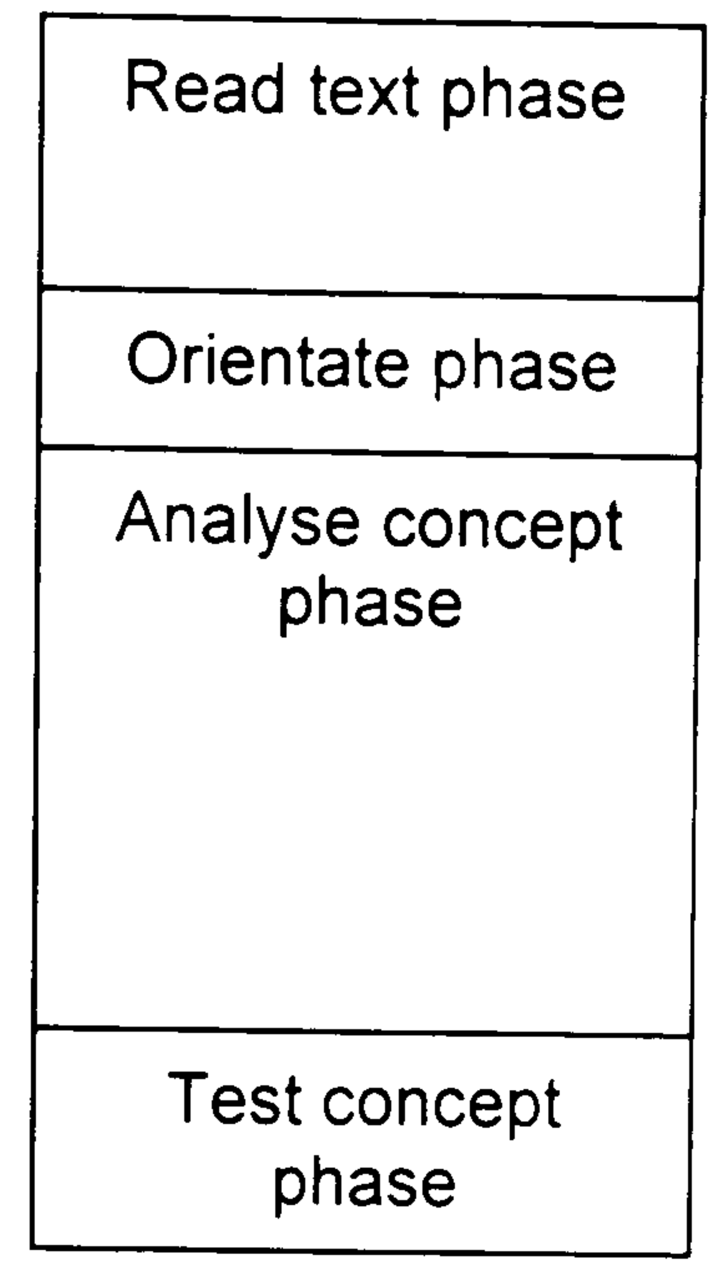
With regard to his approach to information processing, this student's behaviour was characterised by his lack of reflective behaviour during his time using the package. Observational data, as well as coding of his verbal protocol indicated a surface, goal-orientated approach, which is partly evidenced by the total time that he spent on it compared with most of the other students (see Table 116). Similarly, the lack of evidence of his initiating return loops for the purposes of conceptual reinforcement, or to provide further support for concepts that he had failed to understand fully, compared unfavourably with the other students.

Out of fourteen model 2 screens processed by the student, each of which entailed the learning of concepts through the processing of textual and animated elements, he failed to demonstrate any clear instances of reflective behaviour and initiated only one return loop.

Regarding his interaction with the package during model 3 screens, observation and screen capture data both indicated that a trial and error approach was adopted to arrive at a solution in five out of the seven applicable screens.

His approach to model 4 screens differed from the other two screen types in that analysis of his compliance with the predicted model indicated a drop-off in his compliance as he moved through the module. This may be seen as a clear indication of his becoming de-motivated towards the end of his time using the package. Analysis of his compliance with the model indicated that he entered a reflection phase once and initiated no return loops during the seven applicable screens. This would, in part, be due to his inability to validate his final answers during the 'test concept' phase, although analysis of both verbal protocol and screen capture also indicated truncated 'test concept' phases for two of the last three screens visited. An example of this can be seen in his verbalising for screen 2.2.5, which required a two-phase answer using ten's complementary arithmetic. His verbal protocol demonstrates an inconclusive first testing phase, with no secondary analysis and testing phases as would be expected. Although he appeared to be unconvinced by his first phase answer, he made no attempt to initiate a return loop or reflect on his answer.

> *"Type in the ten's complement of the second*
> *number below which when added to ..right.*
> *Right, so the complementary..3727.*
> *9 from 7 is 2.*
> *9 from 2 is 7.*
> *2, 6.*
> *Then why did that (inaudible speech).*
> *So that's, that's 6273 for some reason I think."*



Some further evidence of the student's goal-orientated approach to his use of the package came during the post-EDEC interview when he was asked if there was anything that he would identify as being poor about the package:

> *"The only little glitch in it was the time it took to bring down some of the information when it was showing you...like, I didn't see anywhere where you could speed that up apart from just moving on to the next page, but I just wanted to make sure that the end result was correct before I moved on to the next page."*

His statement implies a degree of impatience with the speed of the animations. This comment is at variance with most other students who commented on the fact that they found them too fast. There is also a degree of contradiction within the statement, where he discusses his need for confirmation of correct answers, when in fact he made little or no attempt to actually validate his answers as he progressed through the module. When I indicated that during observation of his use of the package I had noticed that he seemed to be skimming over some animated elements and that this may have been down to him losing interest his response further highlighted his goal to complete the module as quickly as possible.

> **Researcher:** *"I noticed that you seemed to skim over some of the animations. Was it because they were going too slow and you were losing interest?"*

Student 1: *"Losing interest. Em, well, just if I was fairly sure that I knew what the answer was going to be in the bottom.*
Then I felt that the time taken was just a bit slow."

6.9.2. Student 2

Student 2 was a male in his early twenties. His profile differed from all of the others in that he was the only student who was identified as having a surface strategic component to his results from the Revised Study Process Questionnaire. This particular student was the most computer literate of the sample and gave a neutral response for his general perceptions of the package, as indicated in Table 131. He was also more critical of the aesthetics of the package than any other student. This may be linked to the fact that he often played games on a computer and was used to high value commercial aesthetic interfaces.

Student Profile	
Cognitive Style (Wholist /Analytic)	Analytic
Cognitive Style (Verbaliser/Imager)	Imager
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Surface
Deep/Surface Motivation	Deep
Pre-test Quiz Score	5
Post-test Quiz Score	9
Overall, I liked using the system.	Neutral
I would use this system again in my studying.	Neutral
I would recommend the system to other students.	Neutral
Total spent on EDEC package	63mins.

Table 131

When asked how his approach to learning from EDEC compared with other resources, he confirmed the observed surface and goal-driven approach taken to the package by him:

> *"Eh, in terms of actual worthwhile learning, I think you just work through it. You just go, next page, next page and that's it OK. You just move on then you forget about it, whereas I think if it was used along with other things, it's used to back up.*

His general approach to learning and resource use was further explored during the interview when he was asked how useful interaction with other students was to him in his studies.

> *"Aye, I must admit it is the best way, cos you say, I didn't get this and you go, do you not get it, this is how I got it, and they see it and they go, ahh, I was missing that step kind of thing...Eh, I was studying the other day with two students and that helped me cos I was saying, ah, I think I know this part and then one of them mentioned something and I was like, oh, I forgot about that. No, but I think that group learning is a very good thing because that's when you know your weaknesses and your strengths."*

Observation of his approach indicated a more complex processing methodology than student 1, with much greater use of return loops and a more observable evidence of reflective behaviour during and after screens.

His approach to model 4 type questions often entailed the use of the toolbox facility in order to obtain an answer and work backwards to gain a deeper understanding of the underlying theory. Observation of his behaviour during these screens indicated that he was using the toolbox facility as a trigger for return loops and reflective behaviour.

Unlike student 1, this student highlighted his difficulty in processing animated information during his post-EDEC interview. The following passage from the interview clearly demonstrates the difficulties that he encountered and may go some way to explaining the number of return loops initiated by him during his use of the package.

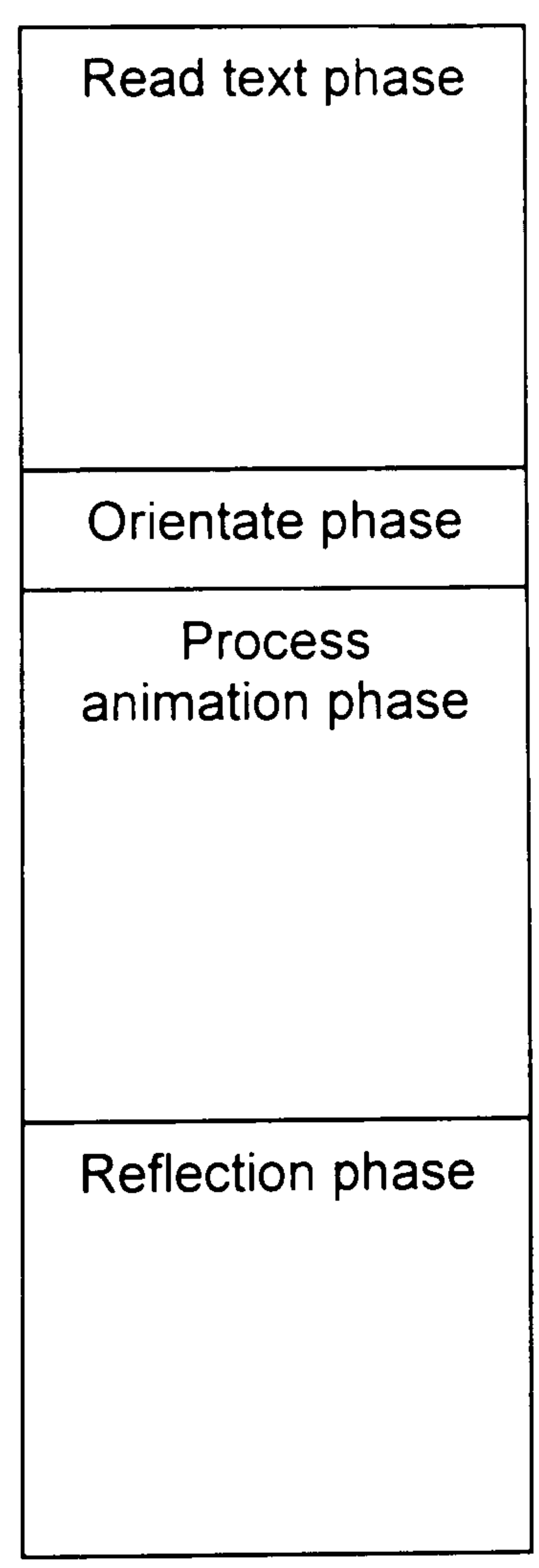
> **Researcher:** *"Was there anything that you didn't like about the package?"*
>
> **Student 2:** *"Eh, the speed of the animations. Like see when it's going down, you're like right, OK, so it's 9 plus 6, right then it might run on to the next bit."*
>
> **Researcher:** *"So too fast?"*
>
> **Student 2:** *"It's just, aye. It's going from 9 plus 9 equals zero, carry 1, then it goes on to the next line and you're like, I'll have to wait until it all finishes then I (laughs) go over it myself."*

Researcher: *"At one point you said, 'I'll just wait til this finishes', were the animations becoming a hindrance that you just wanted to get them over?"*

Student 2: *"No, the animation, I think it's just the fact that it's the speed it was going at. So, right, it was doing steps one to five in a minute, whereas I would do one to five in maybe two minutes. So when it's done all the five steps, I'm maybe just starting one and I thought the speed of it just caused me to go, oh I'll just wait til its finished kind of thing. I'll just do it at my own speed; but it would have been good if you could have controlled it on your own. Like see when it's going down, you're like right, OK, so it's 9 plus 6, right then it might run on to the next bit."*

Clear evidence of the student's problems with processing animated information came during screen 1.2.1 where he had to process a twenty second animation on the binary numbers and the base two. Observational notes as well as his verbal protocol indicated that most of his analytical processing of the concept came after the 'process animation' phase during a final reflection phase, where he processed the concept through consideration of the final static image.

"A more natural base to use is binary.
Work with binary rather than decimal
Power of two.
Binary
Equals one.
Fancy graphics.
Right, starting to get a wee bit lost here.
Right, so it's moving a bit too fast.
Eh, right 101 equals 1 times 2 times 2.
(Inaudible) 2 times 1.
Rrrright, OK.
Right, understand that.
Just had to take time to work that out because the software went too fast."



In general, student 2 exhibited a higher degree of reflective behaviour than most of the other students, with evidence of multiple reflection phases during some screens, which were often accompanied by single or multiple return loops.

When he was asked to characterise himself as a learner, his initial response alluded to a surface strategic approach.

> **Researcher:** *How do you see yourself as a learner?*
>
> **Student 2:** *I'm a spurt learner, as in, when I can be bothered I learn.*
> *"If I think I know it and I'm comfortable with it, I skim it and if, hexadecimals, right, OK, I'm not getting this."*

However, his further description of himself provides further evidence of his deeper, more reflective approach to his use of the package.

> *"I remember there was one question, sitting there for about 20 minutes going, right, OK, back, back. Right, OK, starting to get an answer kind of thing."*

When comparing his approach to model 3 screens with that for model 4 screens, it was clear that there was a difference in his approach to processing the different screen types, with regard to his inclusion of the predicted reflection phase. Although there was clear evidence of his entering at least one reflection phase during five out of seven model 4 screens, where he was required to answer open type calculation questions only two reflection phases out of seven model 3 questions were initiated.

6.9.3. Student 3

Student 3 was a male in his forties. Although he spent the second greatest amount of time on the package, his perceptions of the system overall were not positive ones when compared with other students (Table 132).

Student Profile	
Cognitive Style (Wholist /Analytic)	Analytic
Cognitive Style (Verbaliser/Imager)	Bimodal
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Pre-test Quiz Score	2
Post-test Quiz Score	6
Overall, I liked using the system.	Strongly disagree
I would use this system again in my studying.	Disagree
I would recommend the system to other students.	Disagree
Total spent on EDEC package	67min. 27sec.

Table 132

He put his negative perception of the package down to a more complex fear of failure (see Dweck, 2000, chapter 2) when his perceptions were discussed during the post-EDEC interview:

> *"...I think it's maybe because, I think I (was) probably frightened with it sometimes... I think there's a fear of the, a fear of failure using the technology..."*

His resource preferences were to a large degree defined by his own early educational experience, which was based around *'books and papers'* and was observable in his preference for pen and paper for calculation and note-taking during his use of EDEC when compared with most other students. His responses from the Learning Resource Questionnaire also cited lectures and textbooks as his preferred method of learning.

Further evidence of the student's discomfort with the EDEC package and his preferred approach to learning was demonstrated in his response to being asked how natural he felt working within the EDEC learning environment.

> **Researcher:** *"Would it be fair to say that this kind of package wouldn't be your most natural learning environment?"*
>
> **Student 3:** *"Absolutely. I would get a book, read the chapter, highlight all the key points, make sure I understood the key points, work through some examples, then maybe using the book, put the book aside, read the question and then probably do the example without looking at the answer and then when I felt quite happy that I could sit down and write the*

commutative law, then the other law and the other law and the other law without looking at any text, then I would go and tackle the next questions."

In order to further explore his approach to learning when using the EDEC package, I discussed my observation that he appeared to be using the interface merely as a means of inputting data but appeared to want to learn the underpinning theory in another way. His response discussed his experience with EDEC as well as a more prolonged previous experience with a mathematics package called CALMAT.

> **Researcher:** *"So would you typically use a package like this just to input answers and not for the learning itself?"*
>
> **Student 3:** *"Yes. Yes. That's like the CALMAT. What I did for CALMAT was I did it all, there were two ways for CALMAT.*
>
> *There was the, the just the straight in and practise a test, then sit it, which I knew then, cos it came from school, or you could go the very, very long laborious tutorial work. Understand that three angles equals x and then do the tutorials, and that's the way I did it. I had six log books. I sat, what I did then was I got a basis of learning and by Christmas I hadn't sat a test, and I came in after Christmas and I sat two in one day and then I came in the next week and I sat another two and then I sat one and then I went and studied again for four weeks and then I came in and sat two tests, one test, two tests."*

This goal-orientated approach was also highlighted in student 6's discussion of her use of the CALMAT package.

> **Researcher:** "What was your approach to doing CALMAT? You took lots of notes here, was that how you approached CALMAT?"
>
> **Student 6:** *"Kind of. We kind of cheated with CALMAT (laughs). Em, if you went into the, like before you did the test, if you went in to do all the demonstrations you could write, you could like do all the, the sums and you had all your answers and that, so you could just write them all down, and if you did a few, it would kind of take you through it all."*

Student 7 went even further in suggesting that he used packages such as EDEC and CALMAT in a very superficial, goal-orientated manner when he was asked to discuss his experiences with CALMAT.

> **Researcher:** *"Another example of this type of learning for you came in CALMAT. How did you use CALMAT? Did you work on screen or did you use paper and only use the screen for inputting answers?"*
>
> **Student 7:** *"Yes, basically that's what I done. I basically went to a tutor and basically got him to show me it. How to basically don't want to understand it. Just that's the, whatever it was, do it. He would give me examples. I would learn them and then I would just go and do CALMAT and fire it in."*

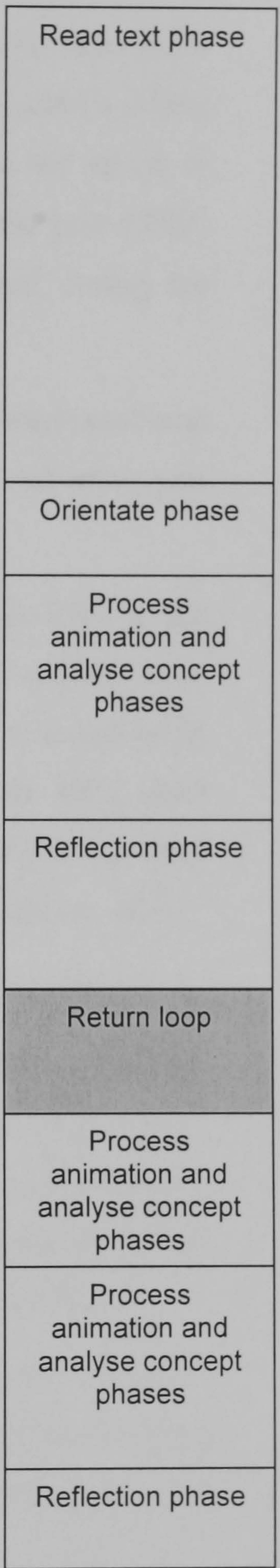
The preceding statements from the students highlighted their perception of standalone packages such as EDEC and CALMAT as assessment interfaces, where the learner's goal appeared to a large extent to be driven by the need to complete the exercise as an 'assessable hurdle' in lieu of gaining a deeper learning experience.

In terms of his processing of information during his use of the EDEC package, Student 3's approach was characterised by his demonstrating reflective behaviour throughout his time on the module (47 coded instances). The data from his verbal protocol, screen capture and observation all indicated that the inclusion of a reflection phase was applied fairly consistently across each of procedural models 2 to 4, thus generally conforming to the predicted models in each case. He was also observed to initiate single or multiple return loops on a number of screens, which were often instigated by a period of reflection.

Whereas student 1 was observed to have taken a trial and error approach to answering model 3 type questions (drag and drop and multiple choice) on five out of seven occasions, student 3 only used a trial and error approach on two. It was noted that on these two occasions once the correct answer had been arrived at, a period of retrospective reflection followed, in an attempt to determine the underpinning conceptual theory.

An example of his following procedural model 2 can be seen in his verbalising during screen 1.3.4 which contained an animated demonstration of hexadecimal addition. The animation component of the screen lasted for 35 seconds.

"Right, hexadecimal numbers.
Hexadecimal addition.
Right.
Hexadecimal addition follows exactly the same rules as decimal and binary.
To add two numbers we take the right hand column, the least and work our way up to the left hand column.
Click on the add button to add the two numbers below.
Right.
To add the two numbers we add the least significant, 7 plus 8...equals F, cos that's 0 to 9 then A is 10, 11, 12, 13, 14, 15, right.
A plus 6, that would be...
A plus 6..A is 10 that's 16.
Nooooo.
It's 10F?
I don't understand that at all.
Rerun that the now.
Need to start that one again.
Right, to add the two numbers...yeah I accept that 7 and 8 is 15.
15 is represented by F in the 16 things, right fair enough.
A plus 6..right.
A plus 6 is zero carry 1.
A plus 6 equals..ten.
So A plus that equals 16.
Right, that was 16, right."



In general, his compliance with the predicted procedural models was consistent throughout his time on the package and was the most complete of all the students in terms of completion of 'test concept' and 'reflection' phases, despite the fact that he demonstrated signs of frustration the further he progressed through the module.

There was evidence of student 3 having problems with the processing of animated elements which at times impaired his ability to learn the concept under demonstration. Observational data partly attributed this to the student's taking notes on paper during some animations, however he also cited the speed of animation as being a problem during his think-aloud session and post-EDEC interview. His taking of notes during animations was discussed during the interview and highlighted a number of issues for him as a learner.

> **Researcher:** *"How did you find the animations? I noticed that you'd stop part of the way through some to take notes while the animation was running."*
>
> **Student 3:** *"I couldn't stop it. I don't think there was a stop. What would have been useful to me is, if, say the animation runs for 15 seconds here, going from A to Z, if I don't understand C, there's no point in watching D, E, F, G, H, right? So if I could have stopped it at the bit I don't understand and running it two or three panes back I would understand, so that's how it is and then there's, there's a point to then what you did."*
>
> **Researcher:** *"Were the animations running away from you at times?"*
>
> **Student 3:** *"Yes, it was keeping going, so I would be trying to, so if there was ten steps in the animation I'd go and four I understand and five loses me, I go back, 1, 2, 3, 4, 5, I get it. Six loses me, 1, 2, 3, 4, 5, 6 gets me. 1, 2, 3, 4, 5...7. 1, 2, 3, 4, 5...8. Because I don't believe there was a facility to stop and then click on and click back and move about the animation."*

In particular, his 'chunking' approach to the processing of information is evident in his discussion. He clearly implies that the continuous nature of the animated elements had a deleterious impact on his ability to process information with obvious implications for his ability to learn.

6.9.4. Student 4

Student 4 was a male in his forties. The analysis of data from the pre/post-test quiz indicated that he had learned the least from the package, with a differential score of 2 compared with a mean differential score of 4.14. His responses in the perceptions questionnaire also indicated that he did not enjoy using the package. which may have been a contributing factor in his low achievement (see Table 133).

Student Profile	
Cognitive Style (Wholist /Analytic)	Wholist
Cognitive Style (Verbaliser/Imager)	Verbaliser
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Pre-test Quiz Score	4
Post-test Quiz Score	6
Overall, I liked using the system.	Disagree
I would use this system again in my studying.	Neutral
I would recommend the system to other students.	Agree
Total spent on EDEC package	55min. 40sec.

Table 133

His attitude towards the package was discussed during his post-EDEC interview and indicated that it would not typically be his preferred method of learning. It also alluded to the goal-orientated approach to the package observed with other students.

Researcher: *"How easy was it to navigate through the package?"*

Student 4: *"It depends on your attitude. You could be at it all day, because it could say wrong answer, try again and you could keep trying again and keep trying again and keep trying again until you get it right, but you might just be guessing and eventually get it right. Whereas I would far rather say, I haven't a scooby, move on. This is not the way I would learn this."*

Evidence from his verbal protocol as well as from the observation log indicated a greater degree of frustration exhibited by student 4 as he used the package than any of the others. This was characterised by a number of statements, utterances and non-verbal mannerisms during his time spent on the module. Examples of these, taken from his verbal protocol, highlight his growing frustration with the package coupled with his increasing de-motivation follow.

During screen 2.2.9: *"(Sighs) Deary me! What is that? Forget it!"*

During screen 3.1.2: *"So multiplying to aaahhh...no idea."*

During screen 3.1.4: *"Well, binary multiplication then will be...get off!"*

When my observation of his growing frustration with the package was discussed during his interview, he alluded to his perception of the package as supporting rote learning, an approach that he seemed uncomfortable with.

> **Researcher:** *"You appear to have become frustrated with the package as you moved through it?"*
>
> **Student 4:** *"Yes. I got to the point where I wasn't understanding it. The understanding wasn't there. Therefore for me that's not a learning process. That's about, I mean if I go into an exam I have to understand it, otherwise there's no point. There's no point in rote learning, learning something for the likes of that and then just banging it in the back of your head and forgetting about it completely. That's useless to me. I prefer to learn and understand something back to front. So that knowledge is always there and I can use it for other things. You never know when it comes in...you know."*

His perception of himself as a deep learner was interesting and was further evidenced during a discussion of his experience of sitting an open-book exam during one of his undergraduate courses. He refused to use his notes during the examination referring to their use as being '*immoral*'.

During discussion about how he learned best, student 4 demonstrated a clear preference for verbal interaction, which may have been expected due to his profiling as a 'verbaliser' in the Cognitive Styles Analysis test.

> **Researcher:** *"So how do you think that you learn best?"*
>
> **Student 4:** *"I learn best from going to lectures and listening to somebody who knows what they are talking about. Em, and given the opportunity then to question. I must be able to go and question. If I don't understand something I'm quite happy to stick my hand up and say can you explain that back to me, and you will do, and I do that quite a lot in classes. Some lecturers like it, some lecturers don't.*

It's generally, sometimes I take it it's because it's interrupting the flow of the lecture, or they, they're not sure, sure what they're talking about (laughs). But, I learn an awful lot more by challenging, em, not challenging the lecturer or the concept, but challenging my own thought."

His auditory preference was further reinforced in his responses to the Learning Resource Questionnaire where he indicated that lectures and discussion with the lecturer were 'vital' to his learning. The students' general tendency to perceive the package as an assessment tool in lieu of a learning resource was also highlighted during discussion of student 4's resource preferences and whether he viewed EDEC as a core or supplementary resource.

Student 4: *"I would go and supplement the package probably with either other Net sites or textbooks. Em, but I think probably by the end of the week I could probably take the package for you. But doing the package alone, on its own, I don't think for me would be sufficient."*

Analysis of his approach to learning during his use of EDEC indicated an initial compliance with the predicted procedural models which dropped off as he progressed through the package. This was particularly evident in his initialisation of a reflection phase during screens, with none evident beyond screen 2.2.3. It was also evident in his pattern of initialisation of return loops during model 4 screens, where he initialised a return loop for the first four screens but failed to in any of the subsequent three.

Further evidence of his becoming de-motivated during his use of the package came through the analysis of his approach to model 3 screens, where he was observed to have entered appropriate analysis and testing phases for the first four screens of this type, but used a trial and error approach for the final three screens.

In general, his approach to using the package with respect to the predicted procedural models could be characterised by his lack of initiation of a reflection phase during model 3 and model 4 screens, although this phase was observed during seven out of fourteen of model 2 screens. An example of the student's growing frustration with the package along with his extrinsic, goal-orientated approach is demonstrated in his approach to one of the final screens (3.1.4). By this stage there was little evidence of a structured approach taken to his processing of information or conceptual analysis. Observation and screen capture highlighted his attempted use of each of the tables and calculators inside the on-screen toolbox facility before briefly attempting an answer through mental calculation prior to giving up on the screen. Although it could be argued that he fulfilled the individual phases of the predicted model, observation indicated that his prolonged orientation phase characterised his approach, where he appeared to be simply looking for a multiplication calculator to achieve a correct answer. Certainly, his reflection phase did not contain any conceptual analysis and there was no attempt made to initiate a return loop, although he clearly did not understand the concept of binary multiplication. It was interesting, however, that he made no attempt to convert the relatively simple binary numbers (1011 and 0011) to decimal as a means of resolving the problem.

"Exercise. Now try the following multiplication. *The tools in the box may be helpful but try not to use them if possible.* *Binary decimal calculator.*	Read text phase
I don't suppose the binary calculator will have...a multiplication on it. *Multiplication table.* *Binary multiplication table.* *Well, binary multiplication then will be...get off!* *Multiplication table.*	Orientate phase
Binary multiplication table. *1 times 1 is 1.* *This is...total guesswork.*	Analysis/calculate phase
1 times 1 is 1. *0 times 0 is uurghh, is 0..and 1 times 0 is 0.* *Right, OK.*	Testing phase
No, I won't bother trying to find it cos I haven't got the scoobiest of an idea how to do that."	Reflection phase

6.9.5. Student 5

Student 5 was a male in his thirties. He was the most vociferous in his dislike of the EDEC package, although Table 134 shows that he differentiated between his perception of EDEC for himself and for others. He also spent considerably less time on the package than most other students at 62% of mean time.

Student Profile	
Cognitive Style (Wholist /Analytic)	Wholist
Cognitive Style (Verbaliser/Imager)	Bimodal
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Pre-test Quiz Score	1
Post-test Quiz Score	4
Overall, I liked using the system.	Strongly disagree
I would use this system again in my studying.	Strongly disagree
I would recommend the system to other students.	Neutral
Total spent on EDEC package	34min. 16sec.

Table 134

When his negative perception was discussed during his post-EDEC interview, he attributed his negative perception to poor short-term memory and his belief that this kind of resource did not promote long-term memory. He also alluded to the role of the animated media in limiting his ability to process information for later recall.

> *"...once its kind of came up, as soon as its went off, that's me forgotten, you know..."*

His inability to process animated information was further discussed with him, prompted by the observation that they often seemed to run too quickly for him:

> **Researcher**: *"I noticed that the animations were kind of running away from you."*
>
> **Student 5:** *"Yeah, it was. As I said a couple of times, it was almost information overload. Eh, it would be easier for me if I could maybe jot down some examples and have these sheets down in front of me, so that I could relate, you know, the first thing that's explained to the second and I can make kind of links."*

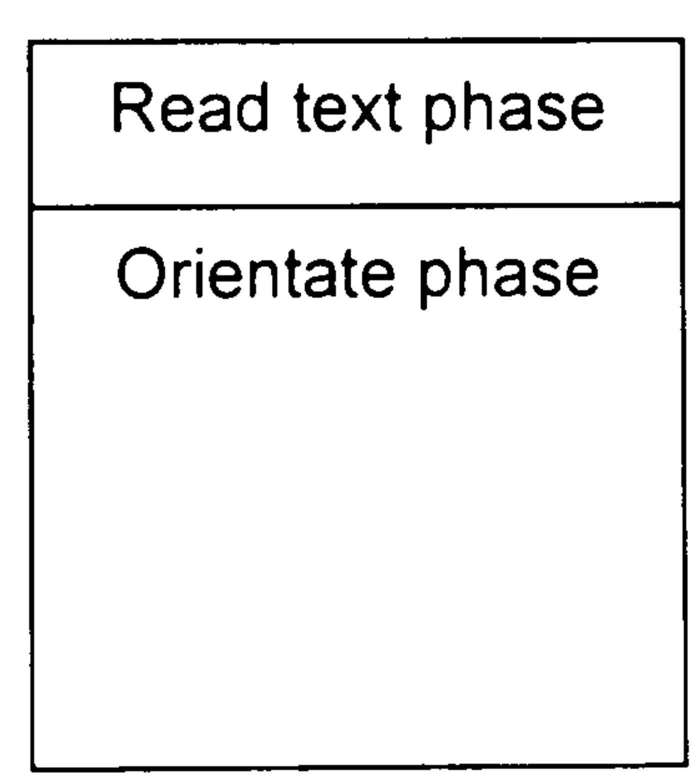
When asked to describe how he learned best, the student indicated that he was a visual learner, although subsequent discussion tended to imply that he was perhaps more of a kinaesthetic (tactile) learner. This may in part be due to his previous career experiences, as he was a cabinetmaker before entering the degree course.

Once again the importance of face to face communication in support of learning figured prominently for this student in his responses to the Learning Resource Questionnaire, with responses of 'vital' for both discussion with tutor and discussion with other students. He reinforced this perception during the post-EDEC interview.

> *"Also talking to people. It's a kind of mutual process of understanding as you talk to somebody. It can go off at a tangent, but this can be kind of helpful..."*

His general approach to using the package could be characterised by the almost complete absence of reflection during and at the end of screens, combined with limited use of feedback during his time on the module. It was particularly interesting that he did not enter a single reflection phase or initiate a return loop during all of the model 4 type questions. An example of this can be seen in his verbal protocol for screen 2.2.9.

> *"Eh, this one has came up...an exercise.*
> *Just reading instructions, again it's quite universal in the way it's laid out and the toolbox has came up.*
> *Again I really don't know...how to manipulate the numbers.*
> *So just move onto the next page."*



His verbal protocol for the screen demonstrates a lack of conceptual analysis and testing during his time spent on the screen, with an extremely truncated model that does not move beyond an orientation phase and which fails to comply with the predicted model. His goal-orientated approach to the completion of the module was perhaps best evidenced in his approach to questions during model 3 screens. During all of the seven screens of this type he was observed to have used trial and error to achieve a correct answer before moving on to the next screen without entering a reflection phase.

6.9.6. Student 6

Student 6 was a female in her twenties. She spent more time on the EDEC module than any of the others and gained the most in terms of her differential score from the pre/post-test quiz (see Table 135).

Student Profile	
Cognitive Style (Wholist /Analytic)	Wholist
Cognitive Style (Verbaliser/Imager)	Bimodal
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Deep
Pre-test Quiz Score	2
Post-test Quiz Score	8
Overall, I liked using the system.	Agree
I would use this system again in my studying.	Agree
I would recommend the system to other students.	Agree
Total spent on EDEC package	77min. 26sec.

Table 135

Table 135 shows her generally positive perception of the package, which was confirmed during the post-EDEC interview.

> **Researcher:** *"How did you think the EDEC package helped you to learn?"*
>
> **Student 6:** *"Em, I thought it was, it was a good package. Em, it gave you kind of relevant information and it was all set out really well.*

She appeared to be less comfortable than the others in the process of verbalising, as she progressed through the module and required prompting on a number of occasions, particularly at the start. This was raised during the post-EDEC interview, where she was asked whether doing the think-aloud affected her learning during her use of the package.

> *"I was, oh, to an extent I kind of was, but as I went on, you know, it was, it was just what I was doing, I was just saying it instead of thinking it. It was a bit embarrassing at the beginning. I got used to it, so it was alright."*

Her responses to the Learning Resource Questionnaire indicated a preference for textbooks and discussion with tutors or lecturers in support of her learning, although she was more equivocal when asked if she'd prefer to have worked from a book.

> **Researcher:** *"Do you like to learn using computer based packages or would have been happier if I'd given you a book?"*
>
> **Student 6:** *"It depends on how big the book was (laughs). But if it was just a wee booklet, then yeah, I'd prefer that, but if it was a big massive book, then I'd stick with that."*

When she was subsequently asked if she'd have preferred to have been given the module in written note form as a hand-out she responded, 'yeah, probably.'

She quickly elected to take notes (via the paper provided) to support her on-screen problem solving activity during model 3 and 4 screens. She was the only student who opted to take notes from static and animated media during demonstration screens (model 2), while others tended to use paper and pen for calculation purposes only. Her note-taking was observed on a number of occasions to take place during demonstration animations, which may have had an impact on her processing ability. She offset this however through the initiation of more return loops than any other student during model 2 screens. The inability to start and stop animated media at will, did however created a degree of frustration as evidenced through her interview.

Researcher: *"So did you find the animations useful then?"*

Student 6: *"I think they were good. Em, sometimes I thought they were a bit long. Cos, I mean one of them I was taking notes and it got to the end and I just missed the end section and I had to go on, and I had to sit through the whole thing again."*

It was clear that she had become familiar with the repeating structure of the module and was observed to take notes from model 2 screens in anticipation of a subsequent question screen. An example of this is shown from her verbal protocol for screen number 1.3.4.

"Just reading through this page again.
OK, I'm just going to write this down.
OK.
I'll carry the one over."

Read text phase
Orientate phase
Analyse concept/ Reflection phase

Because she was taking notes during her processing of the animation, any conceptual analysis generally took place during a final combined analysis and reflection phase. Her use of concept related notes may also have contributed to her performing better than any other student in the post-test quiz, as she was less reliant on retrieval from short-term memory alone than was the case for the others.

Her overall resource use strategy was more complex than most students and demonstrated a fair degree of intrinsic motivation. Even so, there was evidence of a goal-orientated approach to her use of other computer based resources during her post-EDEC interview when discussing her approach to the CALMAT mathematics package.

> **Researcher:** *"What was your approach to doing CALMAT? You took lots of notes here, was that how you approached CALMAT?"*
>
> **Student 6:** *"Kind of. We kind of cheated with CALMAT (laughs). Em, if you went into the, like before you did the test, if you went in to do all the demonstrations you could write, you could like do all the, the sums and you had all your answers and that, so you could just write them all down, and if you did a few, it would kind of take you through it all."*
>
> **Researcher:** *"So you could pick up on a pattern."*
>
> **Student 6:** *Uh huh and then if you went to the test. Quite a lot of the time the numbers that were in the demonstrations came up in the test, so it was excellent.*

Further evidence of her regarding computer and Web-based learning resources as an assessment interface was highlighted during further discussion of her approach to the CALMAT system.

Researcher: *"Did you prefer to work from notes on paper and only use the screen to input an answer?"*

Student 6: *"Yes, very much so."*

Her note-taking during the EDEC module differed from the other students, in so far as she was the only one who used pen and paper for anything other than carrying out calculations, during model 3 and model 4 questions. The inability to start and stop animations caused her problems during demonstration screens (model 2) due to her note-taking. This on occasions led to her initiation of a return loop for further review of the animation before moving on. Her interview highlights her problems with note taking during animations.

Researcher: *"So did you find the animations useful then?"*

Student 6: *"I think they were good. Em, sometimes I thought they were a bit long. Cos, I mean one of them I was taking notes and it got to the end and I just missed the end section and I had to go on, and I had to sit through the whole thing again."*

The fact that she initiated more return loops than any other student during model 2 screens provides further evidence of her inability to effectively process animated material, due to her taking notes while the animations were running. She indicated that she would typically have relied on her notes for information retrieval during question screens and in her general use of computer and Web-based packages of this type.

Her approach to model 3 screens was interesting, with regard to her lack of use of return loops even when prompted by the software. Although there was little evidence of her taking a trial and error approach to these screens, when compared with some of the other students, there was also little evidence of reflective behaviour (one reflection phase out of seven screens) when compared with her approach to model 4 screens (eight reflection phases out of seven screens).

Evidence of a more intrinsically motivated approach to her use of the package came through the time that she spent on the final section of the module. She spent more time on the last five screens than any other student and was still observed initiating return loops towards the end of the module, where most other students had given up. She was also the only student to complete the module and then return to a screen that she'd struggled with previously. Her verbal protocol clearly shows her multiple use of return loops during the binary multiplication section of the module (screens 3.1.3 and 3.1.4). The passage also highlights her problems with processing information from animation for subsequent recall. Her difficulty in initiating recall from short-term memory for information processed from animated media was characterised by her truncated compliance with the predicted procedural model during screen 3.1.4, which entailed prolonged and seemingly confused orientation phases prior to limited analysis and testing phases. Her multiple use of return loops are also shown.

Screen 3.1.3: *It's gone quite fast, so I've just gone back.*

Right, OK.

Screen 3.1.4: *Em (sighs), 1011..0011.*

Em..not really sure what I'm meant to be...multiplying it by.

Em. Just going to use the same one as it was before in the previous exercise.

Em.

Screen 3.1.3: *Just going through this, em... demonstration again. (Sighs). Em.*

Screen 3.1.4: *Don't really have a clue what's...what I'm doing in this question.*

I understood how the demonstration went through it, em, that it was telling you..what was being..em, what bits have been changed and added or...it's not really..telling you what it's being multiplied by.

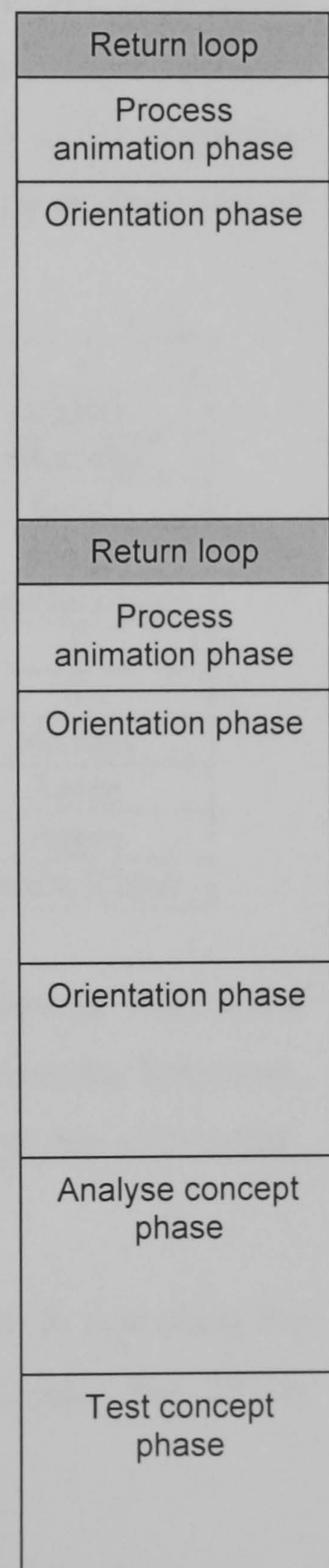
Eh, mm, mm, mm, mm.

Going by the demonstration, I'd say that the top line just stays the same.

It would be 1011.

Em, the bottom line...

Just tried moving the bottom line one place to the left.



Two places to the left..would be. Try that.

I wonder if it's just wanting the whole answer?
Em..try doing it the whole way.
Eh, 100...em..you add these together which would be 111.
Nope.
Nope.
Come back to that one.

Reflection phase
Analyse concept phase
Reflection phase

6.9.7. Student 7

The final student in the sample was a male in his twenties. His think-aloud session was characterised by his reading aloud of most textual content verbatim. Although he profiled as bimodal for the sensory component of the Cognitive Styles Analysis test (Table 136), his approach tended to be more characteristic of what would be expected from a verbaliser style.

Student Profile	
Cognitive Style (Wholist /Analytic)	Analytic
Cognitive Style (Verbaliser/Imager)	Bimodal
Deep/Surface Approach to Learning	Deep
Deep/Surface Learning Strategy	Deep
Deep/Surface Motivation	Intermediate
Pre-test Quiz Score	1
Post-test Quiz Score	6
Overall, I liked using the system.	Neutral
I would use this system again in my studying.	Agree
I would recommend the system to other students.	Agree
Total spent on EDEC package	57min. 23sec.

Table 136

When he was asked how he thought he learned best his response indicated a visual preference, which further contradicts his observed processing behaviour, although the contradiction may go some way to validating his profile as bimodal.

Researcher: *"How would you say you learn best?"*

Student 7: *"It's got to be definitely visual and it's got to be something I'm interacting with...constantly, so the likes of, eh, basically that. If I'm* *doing something over time, then that's fine, I can learn it, sort of develop on it. So I'd say it's more interaction.*

It's like if somebody's, basically I used to find, say for instance when I used to work, say for instance I had to strip down say a press or something, then the guy would tell me how to do it and I'd be like, you'll just have to show me mate. And he'd show me once and that would be it. Telling me stuff or reading stuff is very limited."

Student 7 was generally positive in his perceptions of the EDEC package, although he was less than enthusiastic in his response to the question of whether he liked using the system. He did however state during the interview that he would be willing to use a package like EDEC off-campus, if it supported his learning. While he was equivocal in his perceptions of the package as a learning tool, his pre/post-test differential score (see Table 127) clearly demonstrated that a fair degree of learning had taken place during his time on the module.

Further discussion during the interview on how he learned best provided further evidence of a goal-orientated approach to this student's use of the package and his problems with processing information.

"Eh, but I felt that I had, that there was stuff I was missing, like the thing converting to decimal. I just couldn't get my head round that at all and that was stopping a lot of things that were happening further on, and I realised that, and I was thinking, I'll need to go away back, but I was like that, the game's on (laughs)."

A degree of frustration and de-motivation was observed during his time on the module which was characterised by audible sighs, which became more numerous and pronounced as he progressed. His de-motivation was perhaps most clearly demonstrated in his approach to model 2 screens, where he initiated at least one return loop during each of the first five screens of this type, but none during the subsequent nine screens.

Once again, there was evidence of student 7 having difficulty in processing animated media, leading to a breakdown in his conceptual understanding. This was most clearly expressed during his interview. Although he seemed happy with the format and structure of the animations, he indicated that they ran away from him on occasions.

> **Researcher:** *"Tell me how useful the animations were to you?"*
>
> **Student 7:** *"What I found good was, cos it was stage by stage and it's saying right, this is how you do it. It's telling you how to do it, then it's actually showing you how to do it. I need basically some sort of visual, but to read that, and it was saying, I think at one stage it was sort of, we add and we subtract and then we add again without telling me and I was just like, ah, that's too much."*

The following excerpt from his verbal protocol for screens 3.1.3 and 3.1.4 demonstrates the problem that the student had with conceptual processing during the animation and after it was complete. Although the animation lasted for 34 seconds, there was little evidence of coherent processing taking place during it, and no evidence of any reflection on the concept demonstrated upon its completion. This led to a truncated approach to the procedural model which did not progress beyond a simple *'process animation'* phase and left him both ill-prepared and de-motivated for the following model 4 screen, necessitating the initiation of a return loop back to screen 3.1.3. His verbalising during the *'process animation'* phase followed a similar pattern to that for the *'read text'* phase, with him attempting to read chunks of text verbatim as it appeared on-screen during the animation. It appeared through observation and his verbalising that the cognitive loading required to effectively process the animation blocked his ability to efficiently process conceptual information from the animation.

Screen 3.1.3: *Multiplying binary numbers is done by means of a combination of shifts and additions. For example 5 times A is equal to 1 times A plus 4 times A. To calculate 4 times A we shift A to the left twice...to see how we calculate 5 times 3 in binary.*	Read text phase
1 plus 0's 1. *Plus 0 equals 1.* *Plus 1 equals 1-.* *1 carry...(sighs)...equals 15 in decimal.*	Process animation phase
	Read text phase

Screen 3.1.4: *The following binary multiplication*
tftftftftf. Binary multiplications.
Hmm.
That's me just adding them like the (mumbles).
That times that tststststststs.
Aaahmm, 1 times 1 is 1-.
So it will be 1...and 1...0 and 00
0011.
(Mumbles).
Nope (sighs).

Screen 3.1.3: *(Sighs) (Mumbles)*

Screen 3.1.4: *Binary multiplications-.*
Don't know (sighs).

Analyse concept phase
Test concept phase
Return loop
Analyse concept phase
Return loop
Process animation phase
Read text phase

Evidence from screen capture and observation showed that he had failed to understand the concept of binary multiplication, demonstrated during the animation as a series of additions and shifts. He therefore almost immediately attempted to solve the problem through the use of the toolbox facility, before entering an incorrect answer. It appeared that he was looking for a binary multiplication calculator within the toolbox so that he could achieve a correct answer, however this facility was not available. He therefore merely carried out a binary addition from the binary calculator facility and entered an answer knowing it to be incorrect.

Although he subsequently initiated a return loop in order to further review the demonstration screen (3.1.3) he did not process the entire animation before returning to screen 3.1.4. This is clear from his truncated approach to the procedural models during his final processing of screens 3.1.3 and 3.1.4, with very limited evidence of conceptual analysis and no evidence of testing or reflection phases. There is also clear evidence of his becoming frustrated during the screens.

It is interesting to note that although it would have been possible for him to have simply converted each binary number to decimal for the calculation on screen 3.1.4 (1011 to 11 and 0011 to 3) then multiply as normal, he chose to follow the procedure prescribed by the demonstration animation. This finding is at variance with the argument for a purely goal-orientated approach to the package, although it could be speculated that he had become locked into a particular conceptual system (binary number system) and failed to recognise the possibility of binary to decimal conversion.

However, further evidence of a goal-orientated approach to computer and Web-based packages came through discussion during his interview of his use of the CALMAT maths package. His response to questioning clearly indicates that he also saw the package as merely an assessment tool for inputting answers in lieu of a learning package.

> **Researcher:** *"Another example of this type of learning for you came in CALMAT. How did you use CALMAT? Did you work on screen or did you use paper and only use the screen for inputting answers?"*
>
> **Student 7:** *"Yes, basically that's what I done. I basically went to a tutor and basically got him to show me it. How to basically don't want to understand it. Just that's the, whatever it was, do it. He would give me examples. I would learn them and then I would just go and do CALMAT and fire it in."*

6.10. Validation of Procedural Models

During the analysis of student verbal protocols, each procedural model was tested for conformance with the three validation levels highlighted by Van Someren et al (1994, p. 150). These were:

- Validation of the sequence of tasks within each of the model.
- Validation of the completeness of the model (are there protocol fragments that cannot be coded by the models?)
- Validation of the level of detail and correctness of the model (are there model statements that are never found within the protocols?)

Each of these levels will be discussed in the following sections.

6.10.1. Validation of Task Sequence

The steps taken by each student as they progressed through the module were tested against the predicted procedural models outlined in Table 119. This was done through the development of a number of nodes using the NVivo software package which allowed for the identification and classification of student behaviour from their verbal protocols. This was subsequently triangulated with data collected through observation and screen capture data. It was envisaged that students' processing steps would take the form of a return loop system, with appropriate return loops initiated at any phase during the global process sequence. An example of the how the NVivo software depicted procedural model 1 is shown in Figure 21.

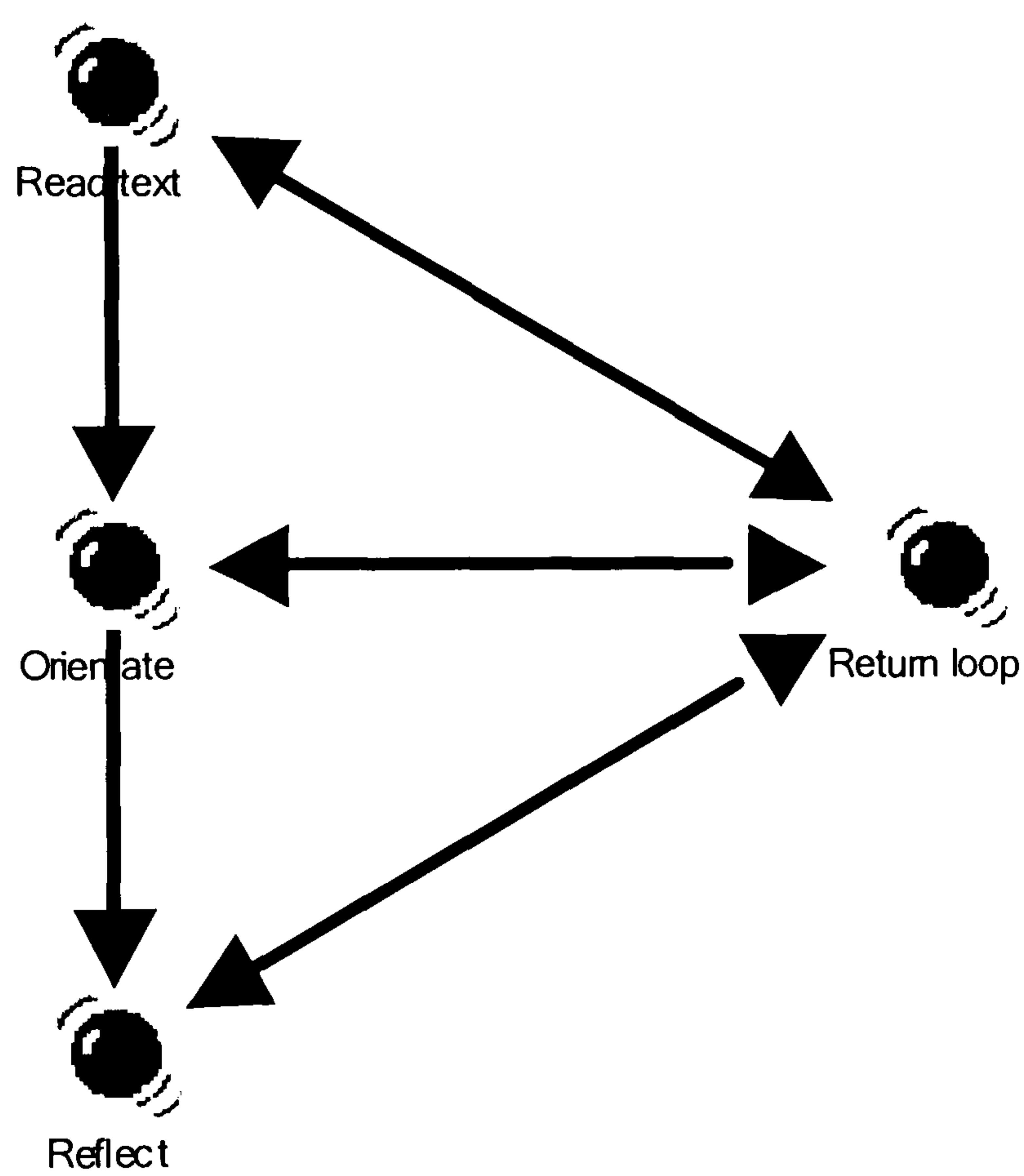


Figure 21 – Procedural Model 1

The following section will consider each student's behaviour during two examples of screens from each of the four procedural models.

6.10.1.1. Procedural Model 1 – Screens with Text Only

The first procedural model typically applied to screens which were intended to introduce the module and provide instructions on its use and have limited cognitive loading in terms of information processing (Figure 22).

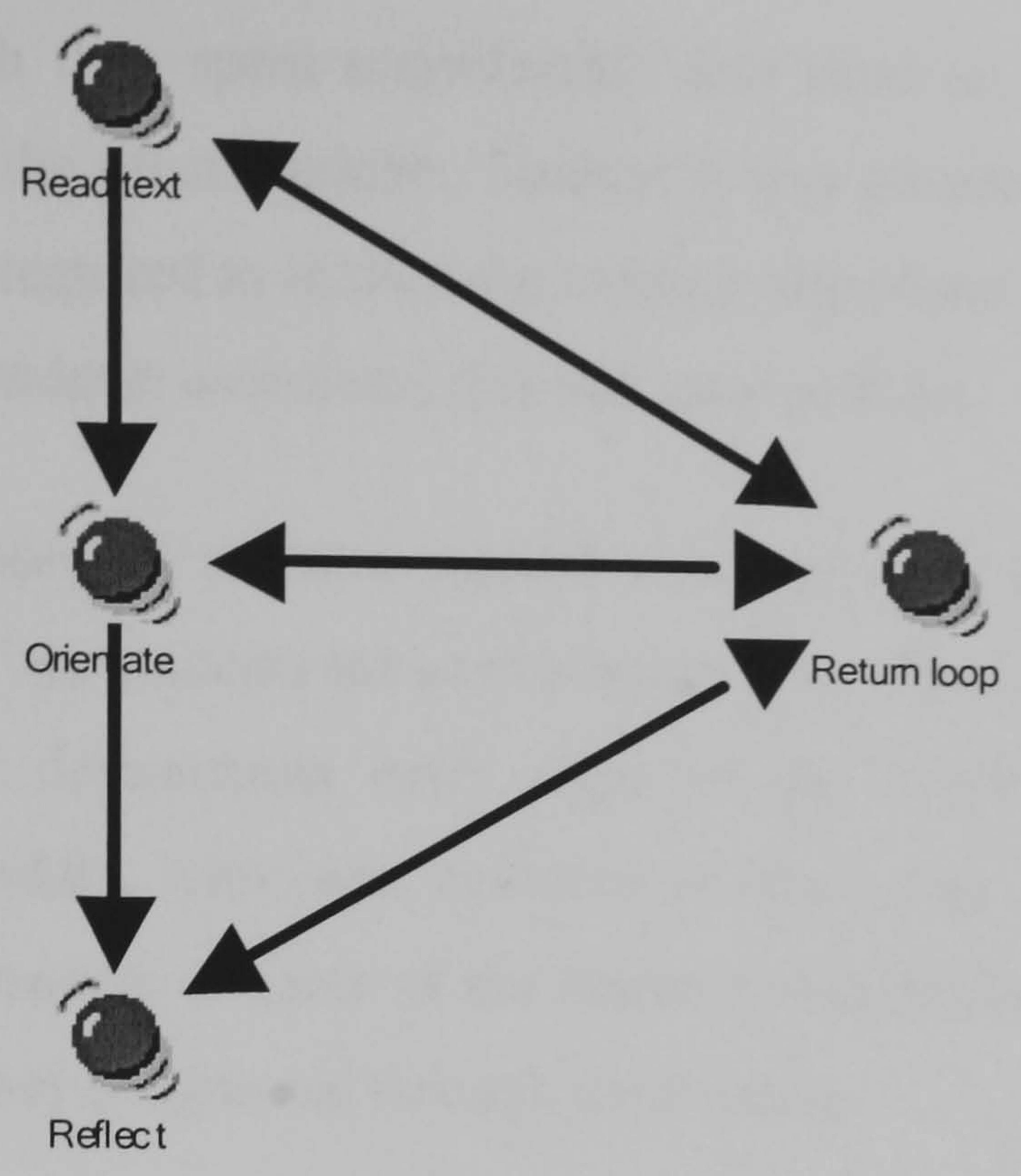


Figure 22 – Procedural Model 1

There were only two screens for which procedural model 1 applied and each of these came at the start of the module. Figure 23 shows screen 1.1.2 which was intended to instruct students on how to use the package.

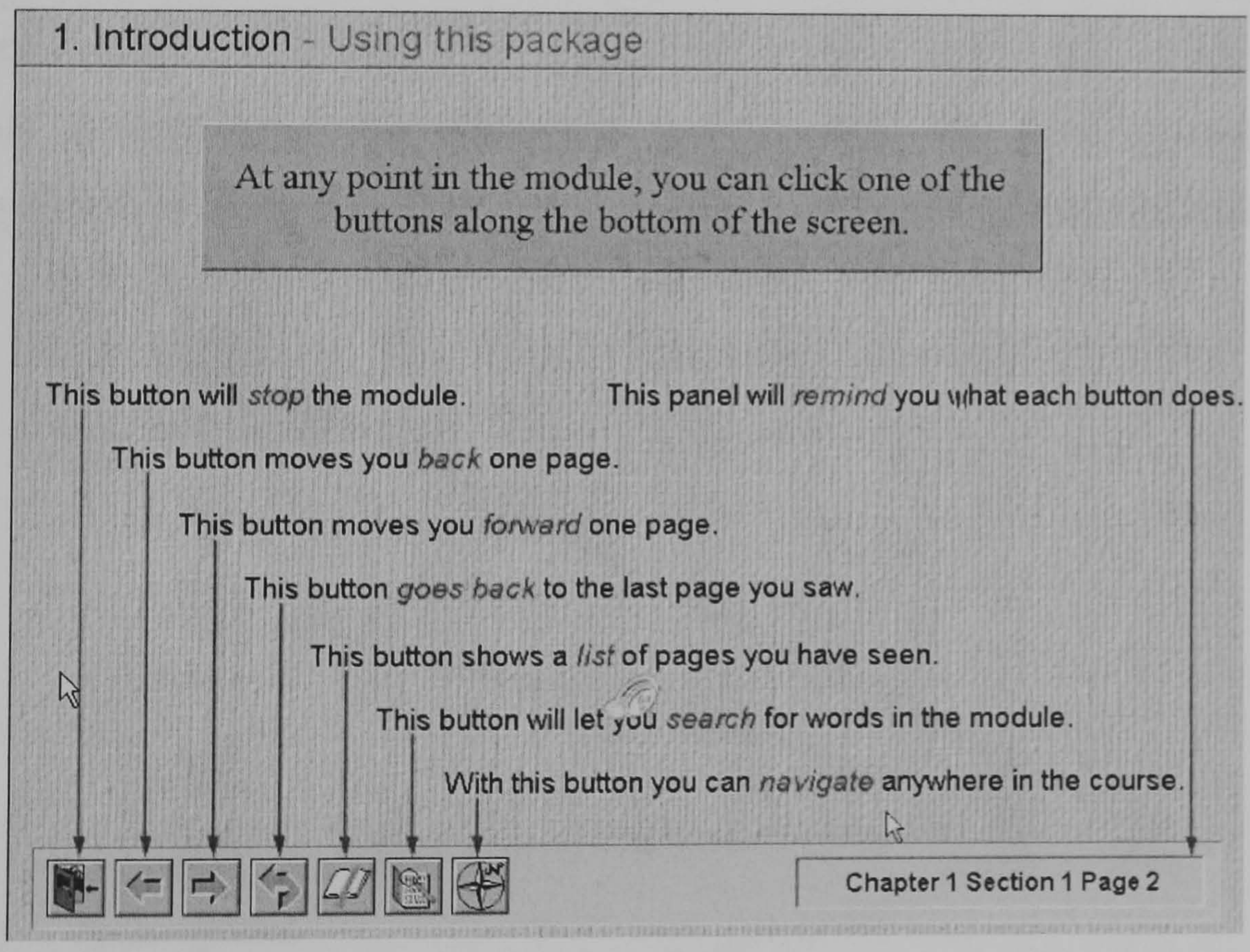


Figure 23

The students spent a mean time of 24 seconds on screen 1.1.2 which gave instructions on how to navigate through the module and the functional elements of the package. They spent an average of 35 seconds reading the objectives of the module (screen 1.1.3). Students 1 and 5 spent more time on these screens than the others, although they spent considerably less time on the module overall when compared to the other students. Student 6 was observed to have failed to click on the button required to initiate the module objectives during screen 1.1.3. although all other students completed this task successfully.

No student was observed to have entered a reflection phase during model 1 screens and none of the students initiated a return loop. The limited time spent on these screens may demonstrate early signs of the students' goal-orientated approach to the module, with clear evidence of skimming through observation and the complete non-use of some of the features highlighted in the instructions on screen 1.1.2 as they progressed through the package.

6.10.1.2. Procedural Model 2 – Screens with Text and Animation

The module contained fifteen screens that included both textual and animated media. Procedural model 2 (Figure 24) predicted that students would sequentially process the textual information on screen prior to an orientation phase, processing the animated media and final reflection on the concept learned. It was also anticipated that a degree of conceptual analysis would take place during students' processing of the animation, and as such, the *'process animation'* coding statement should be seen to incorporate a degree of conceptual analysis.

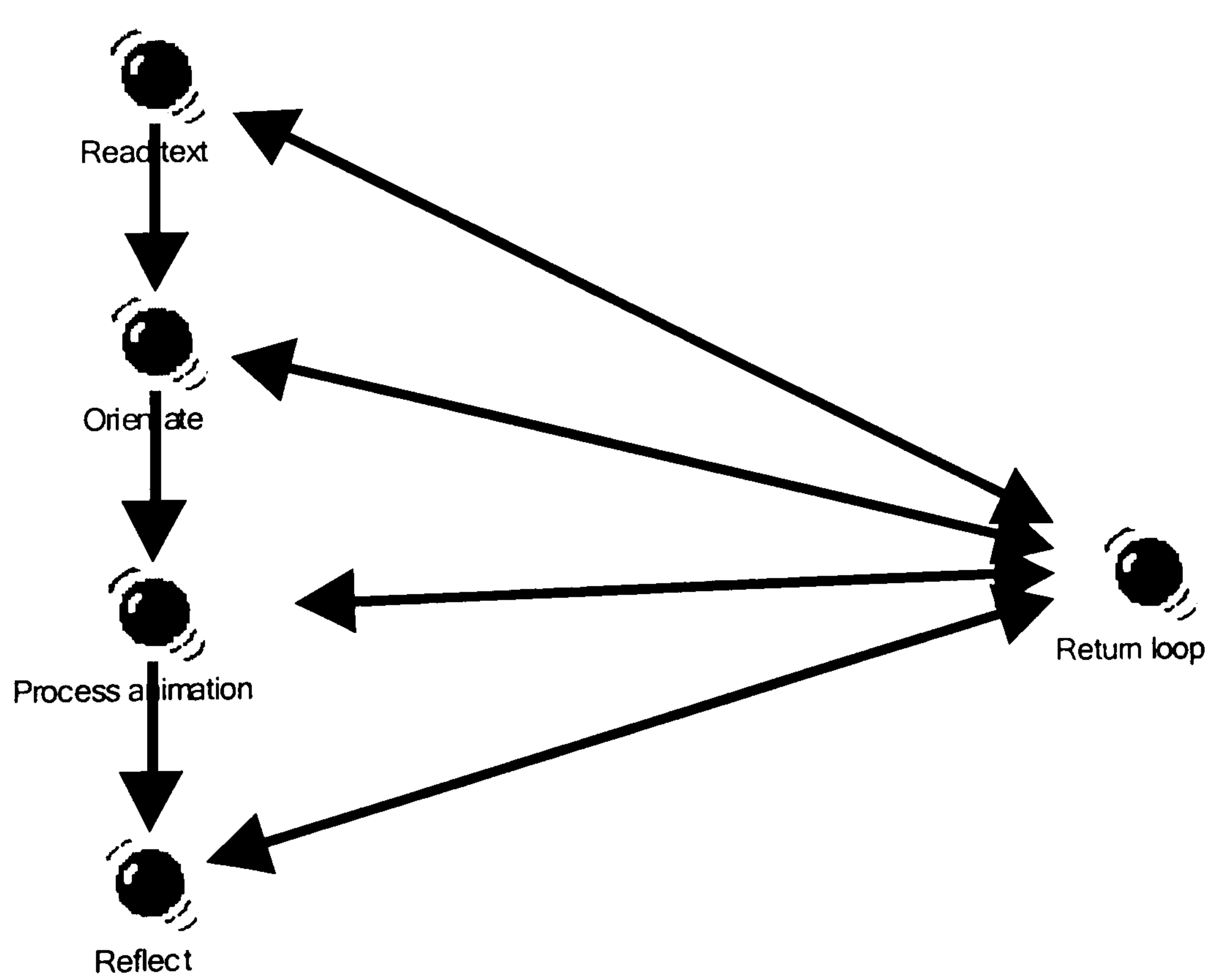


Figure 24 – Procedural Model 2

As discussed earlier in this thesis, it was anticipated that one would observe a different method used in processing text to that for the processing of animated elements. This indeed proved to be the case, as most students' processing of text was characterised by verbatim verbalising of content, while preferring to process animated information silently, even though much of this was textual in nature. The additional cognitive burden of processing sequential images and text was most likely responsible for the lack of verbalising during the *'process animation'* phase of the model. It also proved problematic with regard to students' ability to recall information from animated media. The following examples of student verbal protocols from two screens which subscribed to procedural model 2 demonstrate the students' different approaches to verbalising textual and animated elements.

6.10.1.2.1. Introduction – Binary Numbers Screen 1.2.1

Figure 25 shows screen 1.2.1 which was intended to introduce the binary number system through a textual introduction, followed by an animated demonstration of the mathematical concept of powers of two which lasted for 21 seconds.

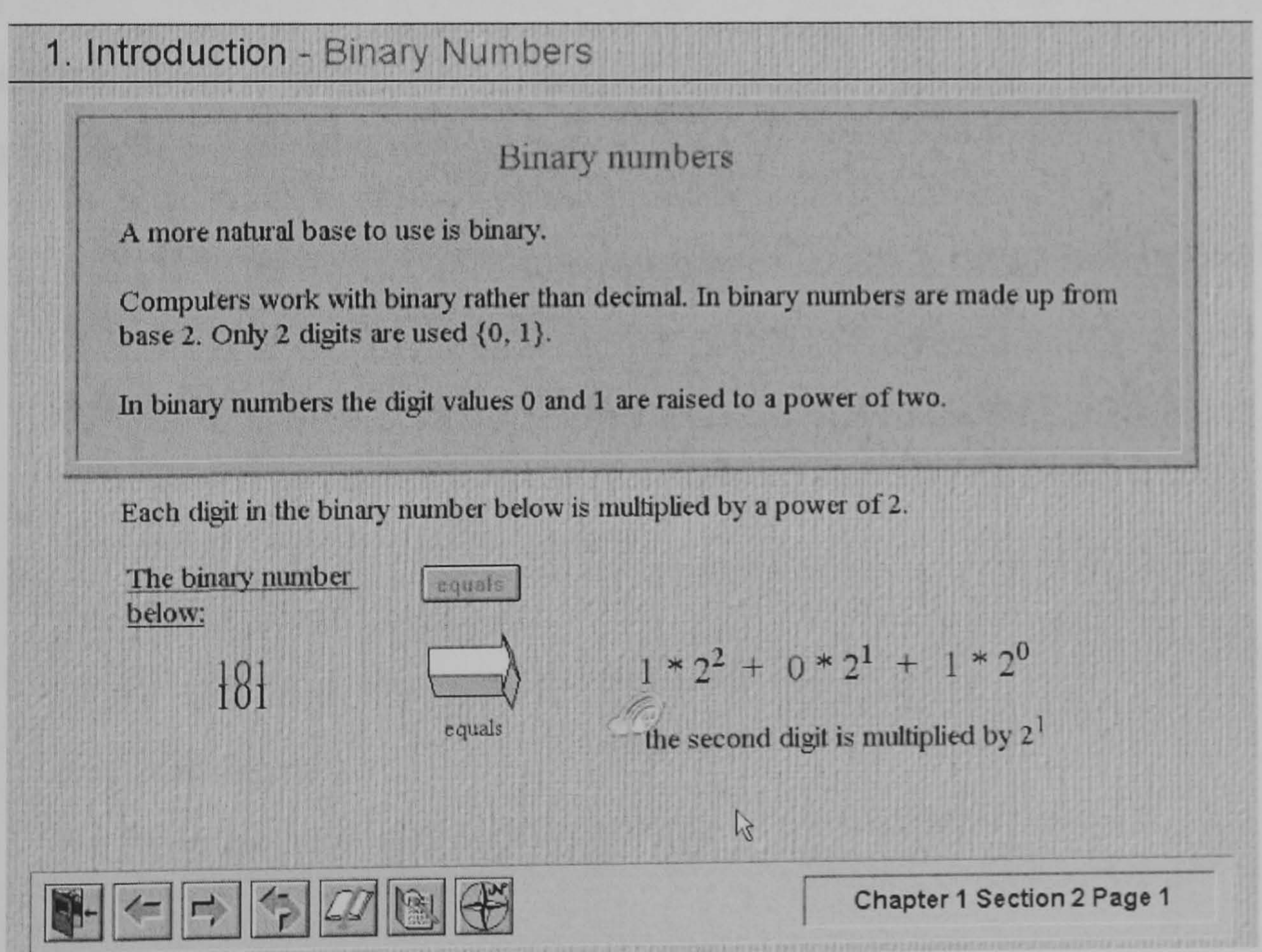


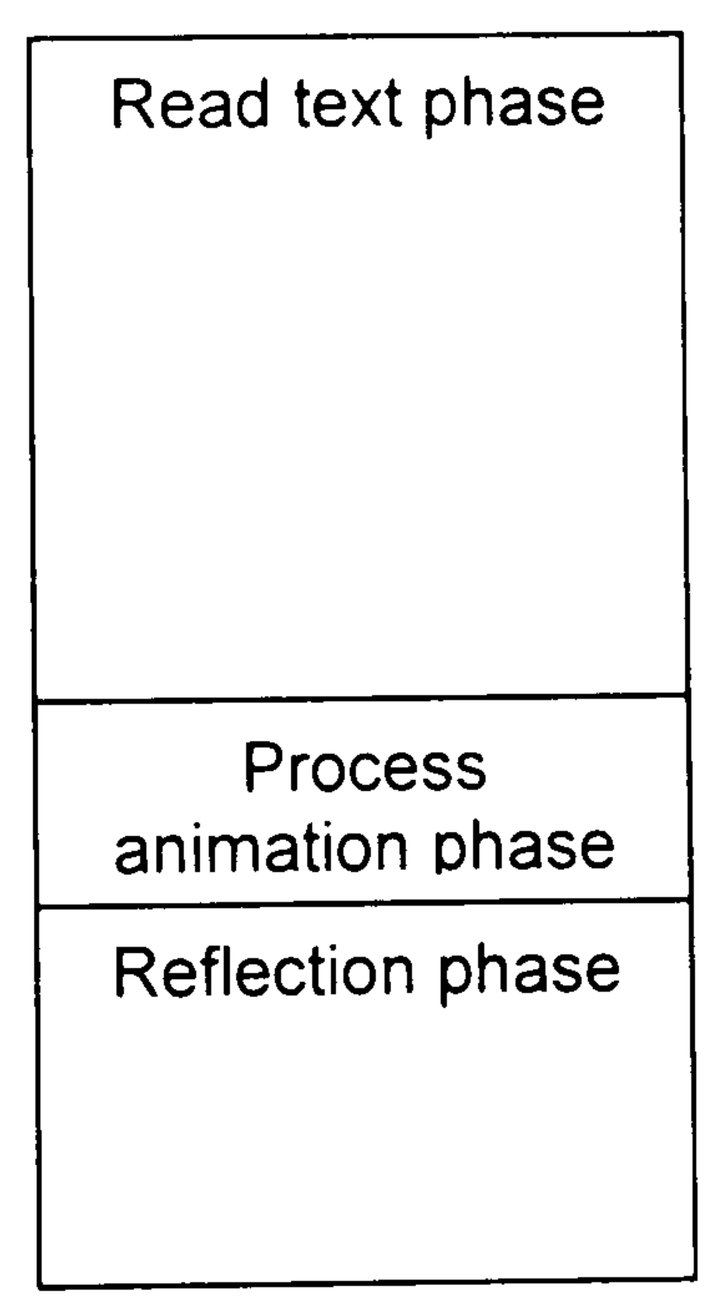
Figure 25

The mean time spent on this screen by students was 114 seconds, although this figure was heavily skewed (std. dev. 129.04) due to one student's time spent on screen of 406 seconds. If this student were removed from the sample the mean time on screen would have dropped to 66 seconds (std. dev. 11.24).

Each student's verbal protocol for the screen demonstrates their different approaches to processing both types of media, and to what extent they complied with the sequence of the predicted procedural model. The following section will report on each student's verbal protocol in turn.

Student 1 (time spent on screen – 49sec.)
Student 1 can be seen to have followed the predicted procedural model by reading the text as a precursor to initiating the animation, although there was no evidence of his entering an orientation phase. It is notable that his verbalising became fragmented and came to a standstill during his processing of the animation. The cognitive burden applied may be responsible for this, as he attempted to analyse the concept at the same time as he was processing the visual media delivered through the animation. His processing of the animation was followed by a brief reflection on the content of the screen, before moving to the next screen. Although he acknowledged that his prediction of the outcome of the animation, *'wasn't what I was expecting'*, he made no attempt to initiate a return loop for further review of the concept.

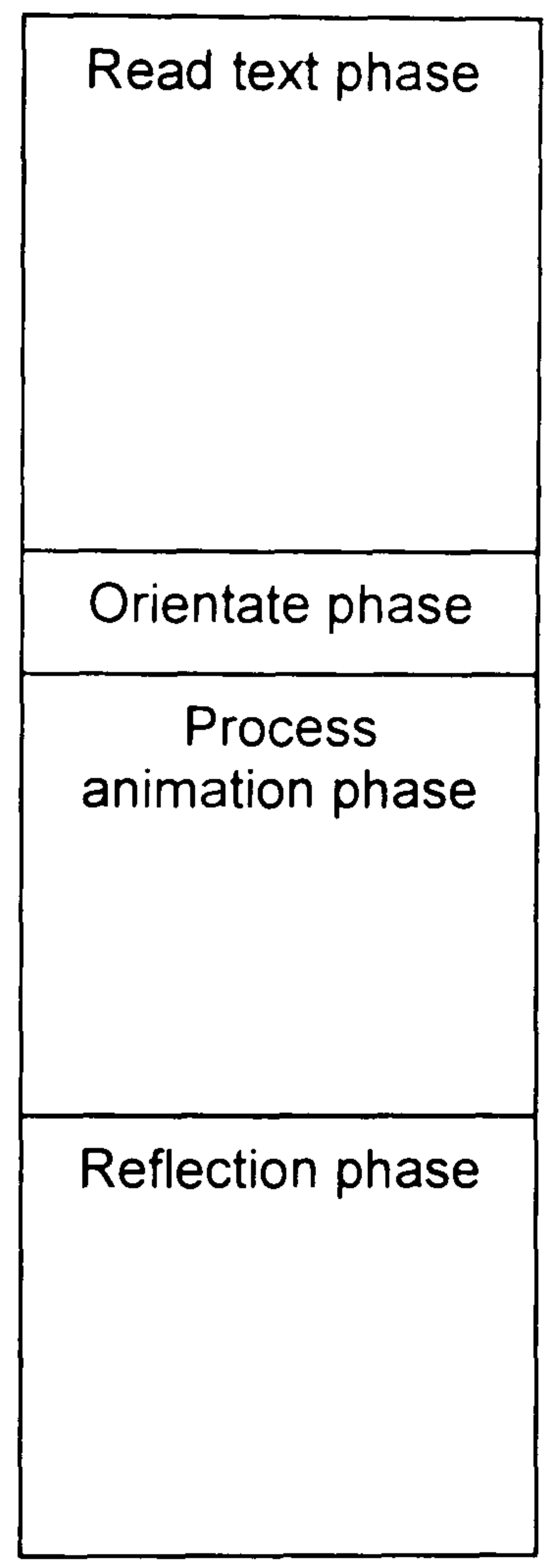
"Eh, reading the statement.
Only two digits, one and zero.
Each digit in the binary number below is
multiplied by a power of 2.
The binary number below equals.
It's actually telling me...
Right... OK, right that wasn't what I was expecting
but... OK, right.
So I'll move on to the next page."



Student 2 (time spent on screen – 60sec.)
Student 2 highlighted having difficulty in processing the animation, finding it too fast. One could assume that this would lead to a breakdown in his ability to process information and therefore may have impaired his conceptual

understanding, necessitating the initiation of a return loop for further review of the animation. In this instance the student instead chose to reflect on the final static image once the animation had finished. Although he completed the expected phases, it was clear that he was using the reflection phase of the predicted model as a separate conceptual analysis phase, due to his inability to analyse the concept during the animation. Although sufficient information was available from the final static image, in the case of this screen, it was not possible to follow this approach during subsequent model 2 screens.

"A more natural base to use is binary.
Work with binary rather than decimal.
Power of two.
Binary.
Equals one.
Fancy graphics.
Right, starting to get a wee bit lost here.
Right, so it's moving a bit too fast.
Eh, right 101 equals 1 times 2 times 2.
(Inaudible) 2 times 1.
Rrrright, OK.
Right, understand that.
Just had to take time to work that out
because the software went too fast."



Student 3 (time spent on screen – 83sec.)

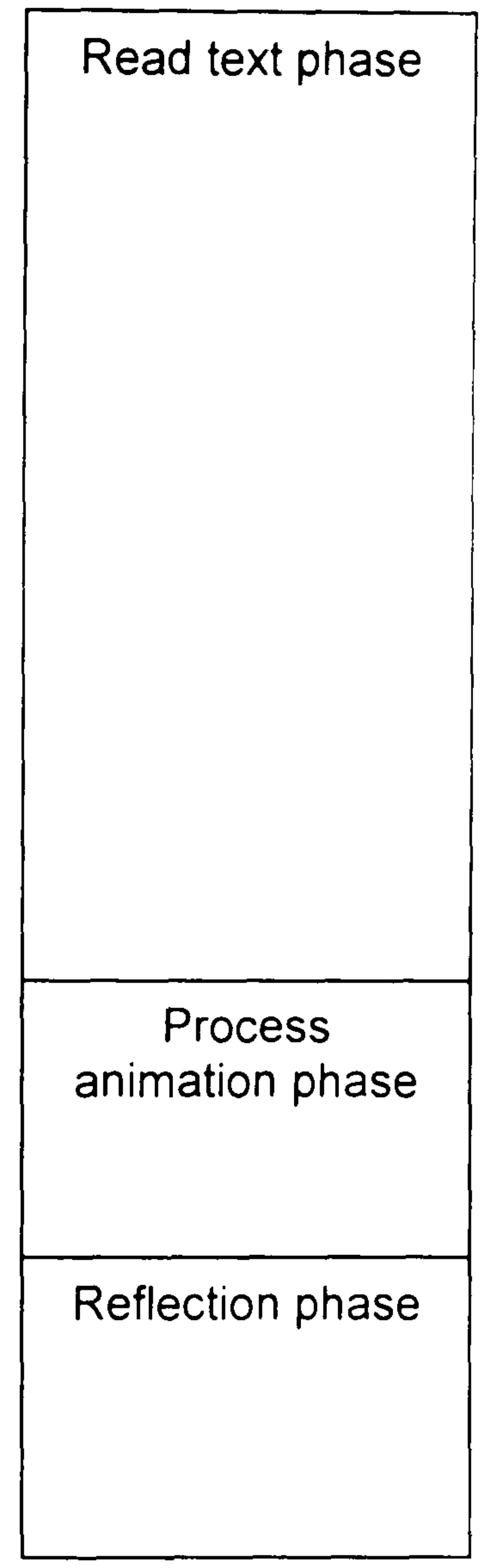
Student 3 processed most of the introductory text in a sequential verbatim manner before initiating the animation. He elected to take paper notes towards the end of the animation, which may imply that his processing of the animation had broken down at this stage. It was also noted that his verbalising stopped during the animation, to allow him to focus on processing the information within it. He was observed to have entered two reflection phases during his time on the screen. During the first of these, he used the introductory text to rehearse the decimal conversion of the binary number 101 prior to his initiation of the animation. The second reflection phase came at the end where he reflected on the concept covered by the screen, although most evidence of conceptual analysis was based around the taking and reviewing of paper-based notes, during and after the animation. He complied with the predicted model, with the exception of the addition of a second intermediate reflection phase. It was evident in his verbalising that he processed the screen in two stages, textual and animated. which is characterised by his multiple reflection phases.

"A more natural base..well it's not natural for me, that's for sure. *Computers work with binary rather than decimal.* *In binary numbers are made up from base 2.* *Only 2 digits are used.*	Read text phase
Right.	Orientate phase
Zero and one. *The binary numbers...right, so we could be zero squared or one squared.* *Each digit in the binary number below is multiplied by a power of 2.*	Read text phase
So one squared is one. *So that's equals 2.*	Reflection phase
Two squared, two to the one aaand two to the zero.	Process animation phase
That's four. *Two to the one is five.* *Right, sorry.* *Right."*	Reflection phase

Student 4 (time spent on screen – 70sec.)

Student 4 also verbalised the textual content almost verbatim, although he remained silent throughout the animation. There was evidence in his verbal protocol of a breakdown in his ability to process information from the animation as it progressed (as has been highlighted with other students), resulting in most of his conceptual analysis taking place via the post-animation static image, in a similar manner to student 2. It was clear that student 4 complied with the predicted procedural model with the exception of any clearly observable orientate phase, although it's sensible to assume that one took place between his read text and process animation phases. As to the extent of analysis of the concept that took place during the animation, this was difficult to determine, although the soundtrack from his screen capture indicated that he made a clear attempt to analyse the concept during the *'process animation'* phase, until his ability to process information had broken down.

"A more natural base to use is binary numbers.
Aye, they're more natural.
Computers work with binary rather than decimal.
In binary numbers are made up from base 2. only two digits are used 0 and one.
In binary numbers the digit values 0 and 1 are raised to a power of 2.
Each digit in the binary number below is multiplied by a power of 2.
The binary number 101 equals.
2 to the power of 2's 4 plus 0 plus 2 to the power...aw where are you going with that.
5, 2 squared.
Right are we starting at this side?
Right, makes sense to the power of 4, 0, 1, 5, right move to the next page."



Student 5 (time spent on screen – 65sec.)

Student 5 spent a considerable amount of time processing the textual screen content, but failed to initiate the animation. His verbal protocol indicated that he became confused with the user interface after reading the introductory text, leading to a truncated procedural model that did not move beyond the *'orientate'* phase. It was also noted that he made no attempt to initiate a return loop. although his verbalising suggests that he was disorientated and confused as to how to proceed beyond the introductory text. It is clear in this instance that student 5 failed to comply with the predicted model, due his confusion with the user interface and what was expected of him. This resulted in a breakdown in his learning process.

"Eh, this is about binary numbers.
This is explaining binary numbers only use 2 digits and the 2 digits used are 0 and 1.
(Lecturer prompt)
Sure, ok, the page I'm on just now after reading the instructions regarding the binary numbers eh, its became, you know, slightly unclear as to you know the next stage whether to move to the next page or..or if there's any questions.
So, move to the next page."

Read text phase
Orientate phase

Student 6 (time spent on screen – 67sec.)

There was very limited verbal activity from student 6, particularly at the start of her use of the EDEC package, which is evident in the lack of verbalising for this screen. She processed the entire animation in silence and became confused with the use of blue on-screen text, which she assumed to be interactive, as is conventional for hyperlinks. In this instance, the student's verbal protocol provides little information on her compliance with the predicted model, although evidence from screen capture and observation indicated that she had complied with the model in her processing of textual and animated content, but made no attempt to initiate a final reflection phase as the model predicted. Her lack of verbal content again indicated problems with students' ability to process animated textual and image-based media at the same time as processing conceptual content.

"OK, I recognise this from Calum's work.
Again, trying to work out how to use this.
Right, OK."

Read text phase
Orientate phase
Process animation phase

Student 7 (time spent on screen – 406sec.)

Student 7 spent considerably more time on the screen that any other student moving through each of the phases of the predicted model, with the addition of a number of return loops during both text and animated phases. It became clear during observation that he was breaking the animation into manageable chunks, for processing, both during and at its end. It was also observed that much of his processing that related to analysis of the concept was carried out from the final static image, which showed the full breakdown of the problem rather than during the animation itself, although by his third review of the animation it was apparent that a greater degree of analysis was taking place in chunks during the animation itself.

"A more natural base to use is binary. *Computers work with binary rather than decimal.* *In binary numbers are made up from base 2. Only 2 digits are used, right.* *In binary numbers the digit values 0 and 1 are raised to a power of 2.* *In binary numbers the digit values 0 and 1 are raised to a power of 2.* *Each digit in the binary number below is multiplied by a power of 2.*	Read text phase
The binary number below equals.	Return loop
A more natural base is to use binary. *Computers work with binary rather than decimal.* *In binary numbers, right.* *Only 2 digits are used, 0 and 1.* *In binary numbers the digit values 0 and 1 are raised to a power of 2.* *Each digit in the binary number below is multiplied by a power of 2.* *The binary number below equals.*	Read text phase
1 times 2 to the power of 2, plus 0 to the power of 2, plus 1 to the power of 2. *Right.* *Equals 5 in decimal.*	Process animation phase
(Mumble) 1 to the power of 2 is 2, plus 0 to the power...1. *(Sighs) Hold on, tftftftf.* *1 to the power, plus 0 to the...2, plus 2 to the 0 is 2.*	Reflection phase
1...multiplied by 2, right.	Return loop

(prompted by researcher)	
Right, OK.	Process animation phase
Right.	
Equals 5 in decimal..mm, which is 2.	Reflection phase
2 to the power of 2 is 2.	
2 to the power of 1 is 2, and 2 to the power.	
Unsure how that works to be honest.	
So let's do it again.	Return loop
A more natural base to use is binary.	Read text phase
Computers work with binary rather than decimal.	
In binary numbers are made up from base 2.	
Only 2 digits are used, 0 and 1.	Read text phase
In binary numbers the digit values 0 and 1 are raised to a power of 2.	
Each digit in the binary number below is multiplied by a power of 2.	
The binary number below equals, which is 1.	
The first digit is multiplied by 2 to the power 2.	Process animation phase
Right.	
The second number is multiplied by 2 to the power 1.	
The third number is 2 to the power 0, so it's 2, 1, 0.	
Right.	
2, 1, 0, right.	Reflection phase
So 1 times 2 to the power 2 is 2 and 0, 1 times 2 is 5, right.	
Thank goodness for that."	

6.10.1.2.2. Negative Numbers – Complementary Numbers Screen 2.2.3

The second screen which will be considered in testing the second procedural model entailed another combination of textual information and animated demonstration (Figure 26).

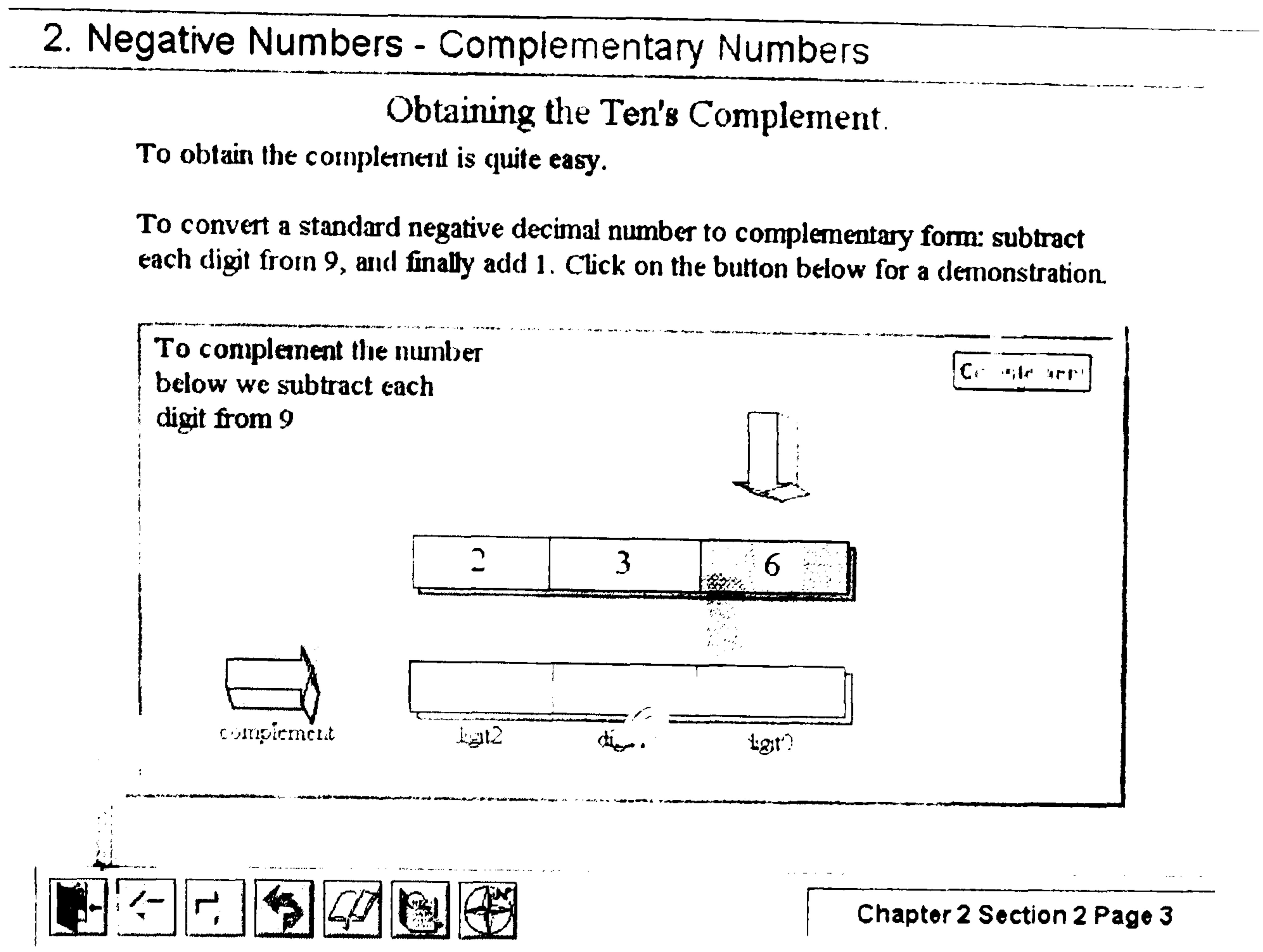


Figure 26

The animation in this case followed a particular format, which was repeated in another number of screens and served the purpose of demonstrating a concept prior to testing of users' knowledge through subsequent screens. The duration of the animation was 38 seconds. The mean time spent on this screen by the students was 98 seconds (std. dev. 46.07).

Student 1 (time spent on screen – 41sec.)

It was evident from the time spent on the screen that student 1 had little opportunity to enter the reflection phase predicted by the model, although his verbal protocol does provide some evidence of conceptual analysis during his processing of the animation. He failed to comply with the procedural model, with no attempt made to enter a reflection phase at the end of the animation. In fact, there was no evidence from his screen capture of any post-animation analysis of the concept whatsoever before he left the screen.

"*To obtain the complement is quite easy.* *To convert a standard decimal number to complementary form.....and finally add 1.* *Click on the button below for a demonstration.* *OK.*	Read text phase
	Orientate phase

°*(Inaudible speech).* *9 minus 2 is 7.* *Right."*	Process animation phase

Student 2 (time spent on screen – 73sec.)

Student 2's verbalising once more demonstrated a more complex procedural model in his approach to the screen than was observed for student 1. He included each of the phases predicted for model 2 screens and showed clear evidence of conceptual analysis during the 'process animation' phase as would have been anticipated. The fact that the animation was split into two sections gave him the opportunity to orientate between sections, thus promoting more effective processing and analysis.

"A wee example. *This might be better.*	
Right, to convert a standard negative decimal number to complementary form subtract each digit from 9 and finally add 1. *Click on the button below for a demonstration.*	Read text phase
Right, to complement number, subtract each digit from 9.	Orientate phase
9 minus 6 is 3. *9 minus 3 equals 6.* *9 minus 2 equals 7.*	Process animation phase
OK.	Orientate phase
Right, now we add one to get the complement. *So 3 plus 1 equals 4-.* *So flip it and add 1.* *Right.* *You can check this by adding those numbers together.*	Process animation phase
Should come to one thousand. *Ah, oh, OK, I just did that.* *Why?* *Why does it come to one thousand?* *Cos we're working on the ten's complement."* *Or we're just grasping.*	Reflection phase

Student 3 (time spent on screen – 170sec.)

Student 3 spent more time on this screen than the mean value for the sample (96 seconds). His verbal protocol clearly complied with the predicted model, with clear orientation and reflection phases apparent beyond the requirements of processing text or animated media. Again, it can be seen that his verbalising became fragmented and stopped during the animation, as he attempted to process its information as well as gain an understanding of the concept under demonstration. Although he appeared to be unsure of the concept during his final reflection phase, he chose not to initiate a return loop for further review of the concept, which may indicate a degree of frustration with the package at this stage.

"Negative numbers. *Obtaining the ten's complement.* *To obtain the complement is quite easy.* *Yeah, easier said than done.* *To convert a standard negative number to complementary form subtract each digit from 9.* *To convert a standard negative number to complementary form.*	Read text phase
What does that mean?	Return loop
To convert a standard negative number to complementary form subtract each digit from 9 and finally add 1. *Click on the button below for a demonstration.*	Read text phase
What should I be looking for? *236.* *What, what am I looking for here?*	Orientate phase
To complement the number we subtract each digit. *So 6 from 9.* *9 from 6, 3.* *9...6.* *Right, and then add 1, right.* *You can check this by adding the numbers together.*	Process animation phase

The answer should come to one thousand.

Why?

Good question.

Right.

Soooooo...you can check this by adding the numbers together.

The answer..should come to a thousand.

236 turns into 764.

64, I don't know why, I don't know why."

Process animation phase
Reflection phase

Student 4 (time spent on screen – 145sec.)

Although student 4 followed the predicted procedural model in terms of its structure, his verbal protocol indicated problems with his ability to process information from the animation at the same time as attempting to analyse the concept being demonstrated. This manifested itself in his need to initiate a return loop and his failure to grasp the conceptual process required to achieve the correct answer. It appeared that the conflicting cognitive demands of processing the animated information, at the same time as analysing the concept of negative numbers in complementary arithmetic was the main contributing factor in his initial failure to understand the concept.

"To obtain the complement is quite easy.

Uuaargh, to convert a standard negative decimal number to complementary form subtract each digit from 9...and finally add 1..Click on the button below for a demonstration.

Subtract each digit from 9, leaving 3, add 1, so you should get 4.

Subtract each digit from 9, 3 and add 1.

Why am I getting 3?

(Sighs) I would have been better starting at negative, it's best negative decimal number to its complementary form subtract each digit from 9.

So 6 from 9 would be 3.

Hold on.

Read text phase
Orientate phase
Process animation phase

Example.

Right, I've done that bit.

Well, that's what I've said, 6, oh I see, right, it's going through it slow.

3 plus 1 right.

9 minus 2's 7.

Right..so then we add 1 to get the complement.

Now, do you add 1 to each digit...separately?

Well, could you not have done that...as...as each one individually...or do you do the whole calculation first and then add 1?

And finally add 1, right, OK."

Return loop
Process animation phase
Reflection phase

Student 5 (time spent on screen – 58sec.)

Student 5's verbalising during the screen clearly highlighted his truncated approach to information processing. He took a very superficial approach to the animation in particular, with little or no evidence of conceptual analysis, which was further highlighted by the absence of any reflection at the end of the animation. His positioning of the cursor during the animation over the button to take him to the next page, coupled with his leaving the page before the animation had finished offers a further insight into his approach. With regard to the procedural model, it was clear that he had not fulfilled the components of the model, as was typical for this particular student.

"Ok so moving onto the next page again about complementary numbers, a table of tens complement.

Just navigating the page.

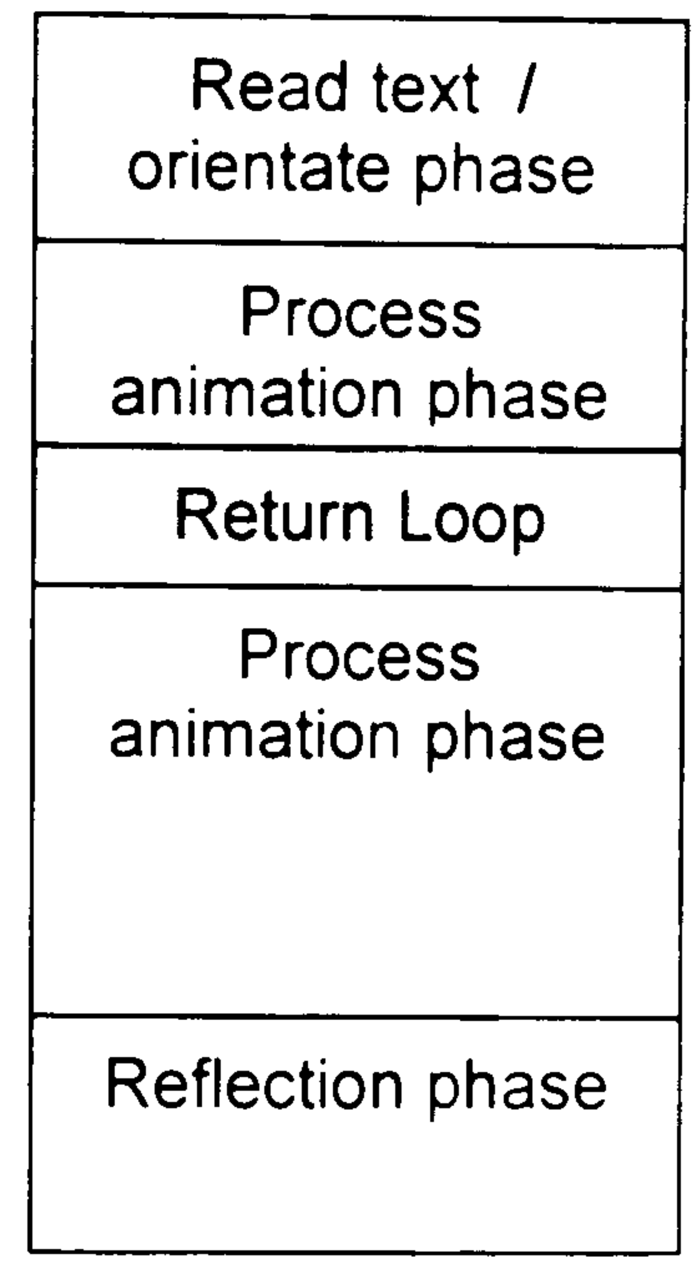
On the next page now."

Read text phase
Process animation phase

Student 6 (time spent on screen – 118sec.)

Student 6 effectively followed the procedural model through a combination of information processing from the screen and note-taking. She was observed to have taken notes during two separate reviews of the animation and also upon the completion of its second run. It is probable that her initiation of a return loop to allow a second viewing of the animation was necessitated by her note-taking during the animation first time round. She effectively separated her information processing of the animation from her conceptual processing by analysing the concept from notes at the end of each run of the animation along with a final reflection phase.

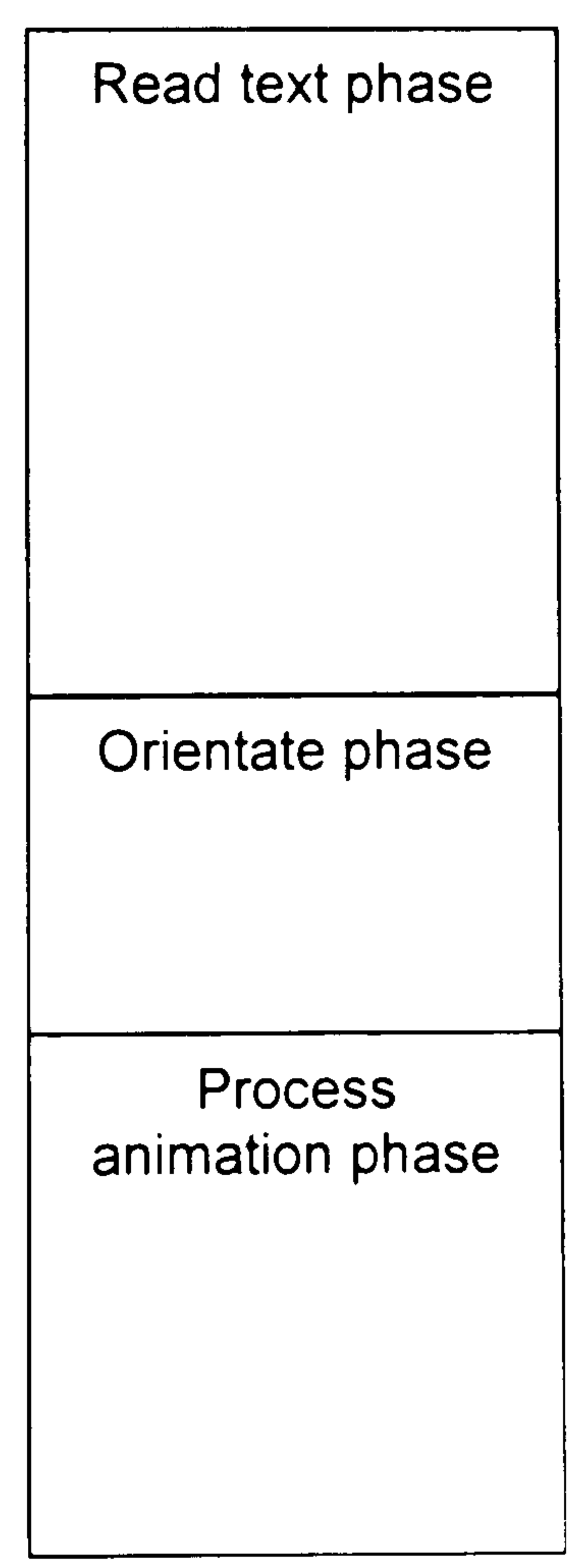
"At the moment it's just telling me that em..you're just subtracting 9 to get the answer.
That was 2, 3, 6.
Try it again.
Take away 9.
Sorry, 9 take away the number.
3...the take away three would equal 6.
Then you're adding on the 1.
OK."



Student 7 (time spent on screen – 70sec.)

Student 7 also complied with the procedural model with clear evidence of orientation and reflection phases in support of his processing of textual and animated information from the screen. Observation during his time on the screen indicated that he started the animation while he was still processing textual information, leading to problems during the *'process animation'* phase. This may also have been responsible for his carrying out much of his conceptual analysis during the final reflection phase from the final static frame of the animation.

"To obtain the complement is quite easy.
To convert a standard negative decimal number to complementary form subtract each digit from 9 and finally add 1.
Subtract each digit from 9 and fina...click on the..for a demonstration-.
To complement the number below we subtract each number from 9, so 3...6...7.
Right.
Then we add 1 to get the complement.
OK-.
Complement of 236..(sighs)...the answer should come to 1000.



Why because it's 999...plus 1, which is 1000. Right-."

Reflection phase

6.10.1.3. Procedural Model 3 – Screens with Interactive Elements

Screens that conformed to procedural model 3 typically contained an interactive element or elements that were designed to test the current concept. The procedural model showing the predicted sequence of phases is shown in Figure 27. This type of screen typically included one or more multiple choice and/or drag and drop questions. Both of these interactive elements were observed to have caused problems for some students, who failed to either recognise the interactive element, or did not immediately understand how to use it.

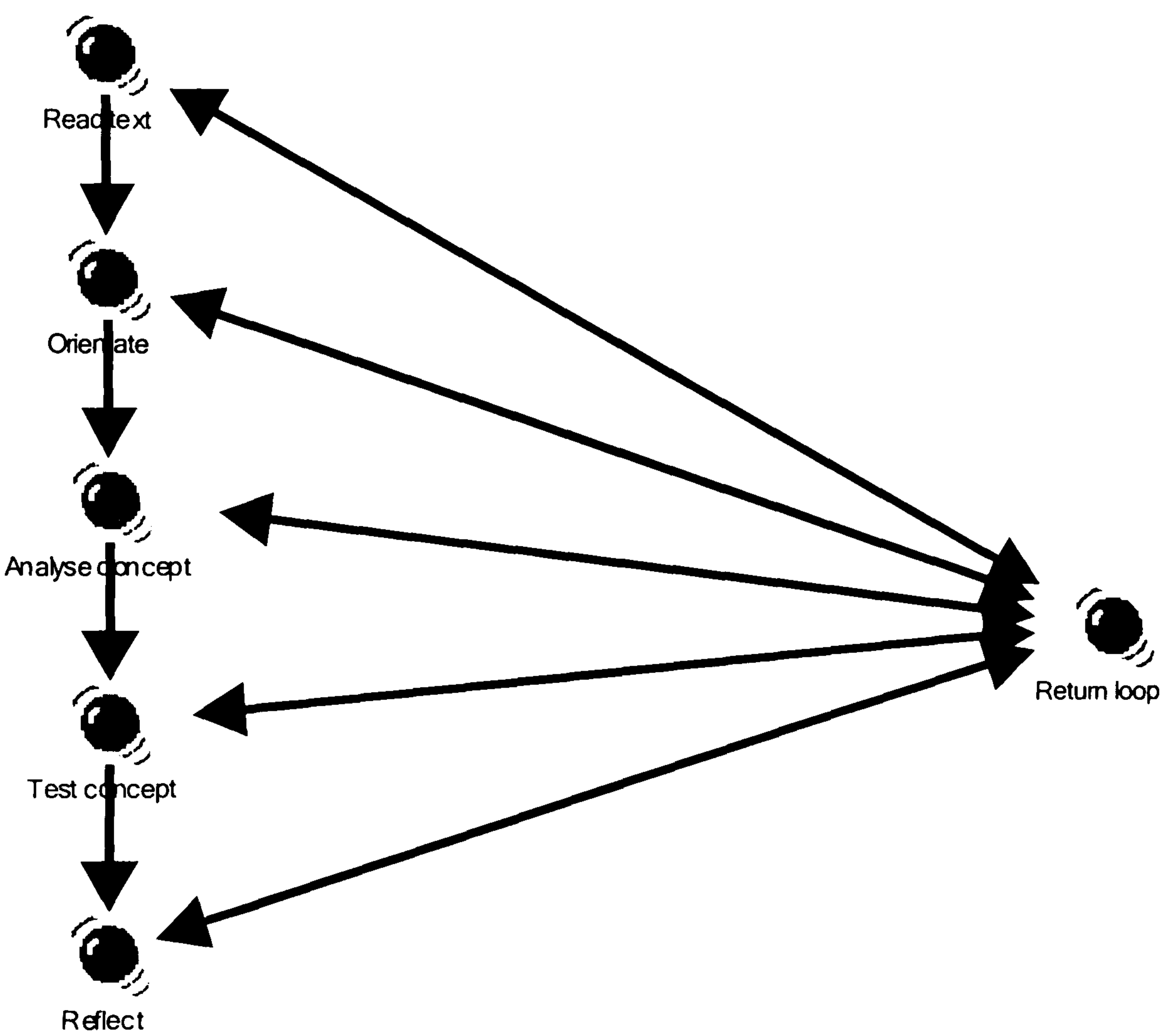


Figure 27 – Procedural Model 3

6.10.1.3.1. Introduction – Binary Numbers Screen 1.2.3

Screen 1.2.3 was intended to test students' conceptual knowledge of the binary number system and its benefits over the decimal system. The screen incorporated two types of question, one being a drag and drop, where words were expected to be dragged into their corresponding spaces in a sentence, and a multiple choice question with three possible answers. A mean time of 53 seconds (45.00 std. dev.) was spent on this screen. Figure 28 shows the composition of the screen.

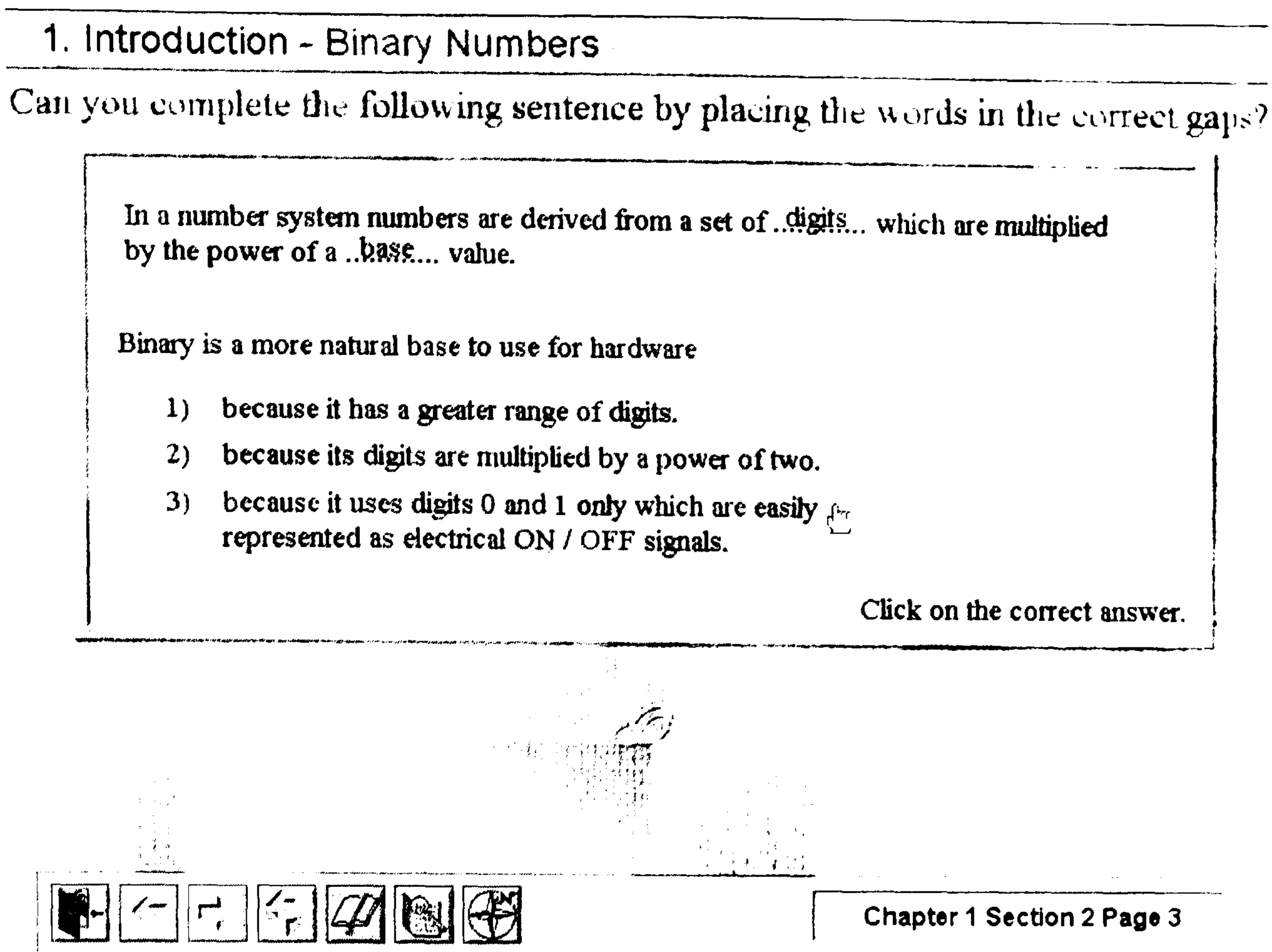


Figure 28

Student 1 (time spent on screen – 40sec.)

This student's verbalising during his time on screen 1.2.3 indicated a truncating of the predicted model, with little, if any evidence of conceptual analysis having taken place prior to his testing of the concepts through the insertion of an answer. Although he got the first question, which was a 50-50 chance wrong, he made no attempt to initiate a return loop or reflect on how he had arrived at the wrong answer, beyond rectifying his mistake, even though the software prompted him to return to the previous page. For the second multiple choice question he both verbalised an incorrect answer and left the screen without checking this answer, even though the on-screen instructions explicitly indicated that the user should *'click on the correct answer'*.

Quotation	Phase
"In the number system numbers are derived from a set of.	Read text phase
Right, got that the wrong way round, right.	Test concept phase
Binary is a more natural base to use for hardware.	Read text phase
Because its digits are multiplied by a power of two.	
Digits."	

Student 2 (time spent on screen – 35sec.)

Student 2 more or less fulfilled the predicted model for the first part of the screen (drag and drop question). His reading, analysis and testing phases took place more or less simultaneously as he dragged answers to their appropriate spaces while processing the text within the sentence. Like student 1, he failed to understand that he was expected to click on a correct answer for the multiple choice question, and instead assumed that each answer options were correct statements.

"Right, in a number systems are derived from a set of...eh, digits.	Read text / analyse concept / test concept phases
Got that OK.	Orientate phase
By the power of a base value.	Read text phase
OK.	Orientate phase
Binary is a more natural base to use in hardware *Because it has a greater range of digits.* *Because its digits are multiplied by a power of two.* *Because it uses digits 0 and 1 only which are easily represented as on and off.*	Read text phase
Simple enough."	Reflection phase

Student 3 (time spent on screen – 30sec.)

Student 3 had no problems with either the interface or the questions and processed the on-screen information in line with a truncated version of the predicted model, with no requirement for an orientation phase and no final reflection. He was observed to follow the model appropriately during the first part of the drag and drop question, however due to the 50-50 nature of the question, he spent no time analysing or reflecting on its second part of the question since he knew it was correct. He did however include a reflection phase after answering the multiple choice question, in order to review his answer.

"Right..can you complete the following sentence by placing the words in the correct gaps. *In a number system which is derived from a set of...*	Read text phase
I suppose if one's right, the other one has to be right. *Binary is a more natural base to use for hardware.*	Analyse / test concept phases

Right, OK.

Because it uses digits and is easily represe...on off."

Reflection phase

Student 4 (time spent on screen – 37sec.)

It can be seen in student 4's verbalising during this screen that both the '*analyse*' and '*test concept*' phases were implemented non-verbally, although observation and screen capture confirmed that he achieved a correct answer for both questions. Again, there was no requirement for, or evidence of a reflection phase in this instance.

"Number systems are derived from a set...number
systems are derived from a set of which
are multiplied to the power...(mumbles), base.
Binary's the more natural base to use for hardware...
Because it has a greater range of digits.
Because its digits are multiplied by a power of two.
Because it uses zero and one which are easily represen...
Next page."

Read text / analyse concept / test concept phases

Student 5 (time spent on screen – 150sec.)

Student 5 entered a prolonged orientation phase during both components of this screen, which concurs with his processing approach to previous screens. In a similar manner to student 1, he chose an incorrect response to the drag and drop question, but opted not to initiate a return loop as prompted by the software and instead inserted what he now knew to be the correct answers before moving on to the multiple choice question. His transcript demonstrated fulfilment of the predicted model for the multiple choice question, with the exception of a reflection phase at the end of the question, even though he acknowledged that he had used a trial and error approach to gain the correct answer.

"Again this one is about binary numbers and there's
gaps to fill in..eh, the spaces eh, for the, for the missing
words, its like the other, eh, I just did a couple of
minutes ago and its quite clear that you just left click on
the, eh, the word bank and, and pull it into place.

Read text / Orientate phases

Eh, I tried the first one got that wrong so there's only one of two so there's a 50/50 chance so I'm going to go for another one and that's correct.	Analyse / Test concept phases
Eh, again I'm just reading on the rest of the page. And it's a kind of multiple choice question, eh, the question being binary is a more natural base to use for hardware. And I'm just reading the questions to see which one I think is most appropriate.	Read text / Orientate phases
And I'm going to go for number 3 and I was correct...that was a fluke. Ok so I'm gonna move to the next page."	Analyse / Test concept phases

Student 6 (time spent on screen – 35sec.)

Although there was a lack of information from student 6's verbal protocol, she did achieve a correct answer on the first attempt at the drag and drop question through combined *'read text'*, *'analyse concept'* and *'test concept'* phases. She however failed to attempt the multiple choice question, as did students 1 and 2, indicating a problem with the user interface.

"My head's a bit blank at the moment (laughs). Em, just reading through all the information. OK."	Read text / analyse concept / test concept phases

Student 7 (time spent on screen – 44sec.)

Student 7 also answered the drag and drop question incorrectly in the first instance, although in this case it may have been due to the lack of an orientation phase, as the software prompted a return to the previous page before he appeared to have completed his answer. This led to a breakdown in the model, as he subsequently inserted the correct answers based on the earlier feedback from the software. He quickly selected the correct multiple choice response to the second questions after reading through the options aloud before entering the analysis and testing phases. Again, there was no evidence of his initiating a reflection phase prior to moving to the next screen.

"In a number system numbers are divided from a set of...a set of digits...which are multiplied by the power of a base value.
Binary is more natural to base to use for...binary is a more natural base to use for hardware.
Because it has a greater range of digits.
Because its digits are multiplied by a power of 2.
Because it uses digits 0 and 1 only which are easily represented as electrical on and off signals.
Yep."

Read text / analyse concept / test concept phases

6.10.1.3.2. Negative Numbers – Sign and Magnitude Screen 2.1.2

This screen required students to interact through clicking on a combination of buttons to give a negative decimal value of -2. The students spent a mean time of 86 seconds on this screen (std. dev. 40.44). Figure 29 shows the screen with the interactive buttons positioned at the bottom.

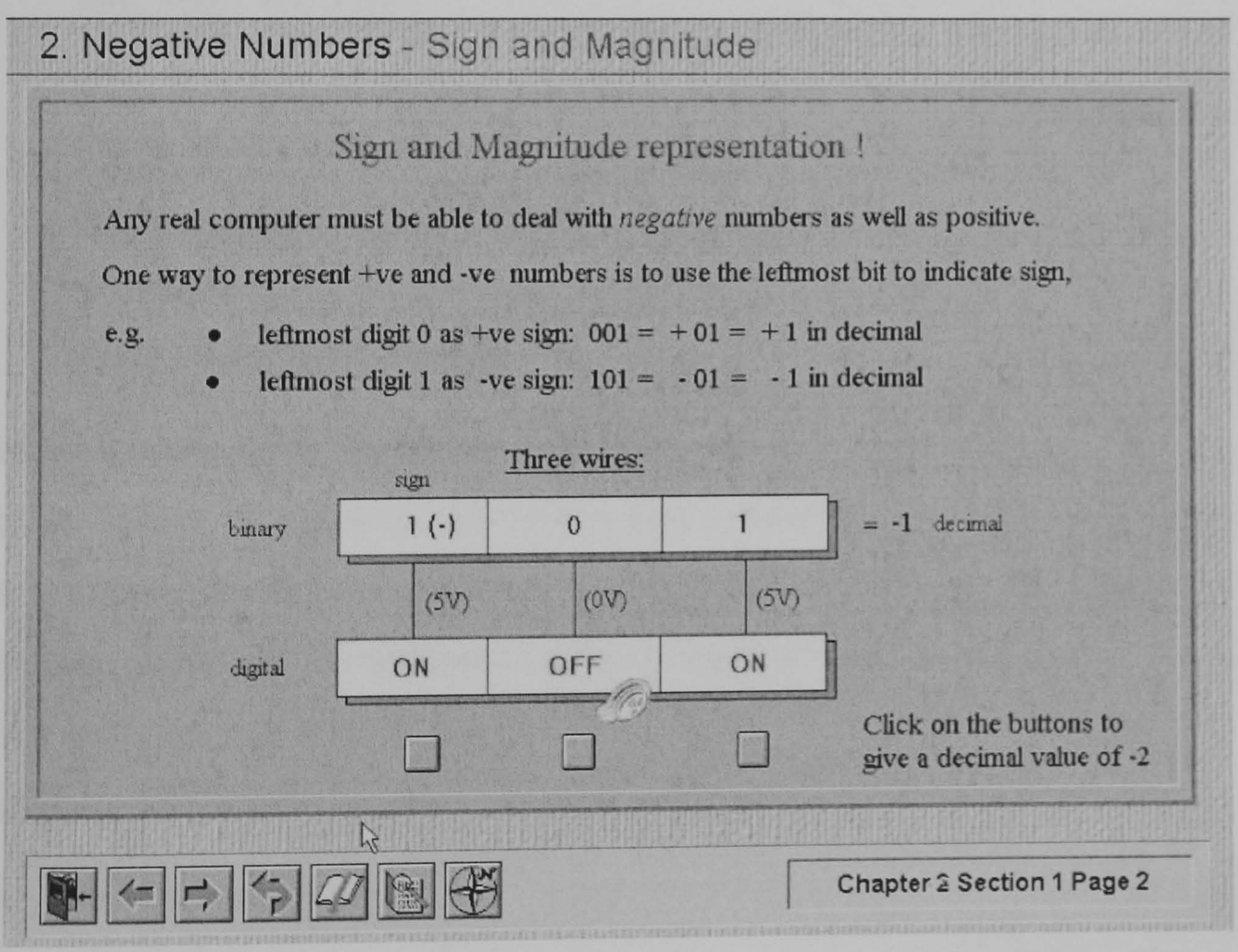


Figure 29

Student 1 (time spent on screen – 69sec.)

By this screen, student 1 appeared to be generally skimming over textual content, which is evident in his fragmented verbalising of screen text. He did however follow the predicted model more rigorously that during screen 1.2.3. with some evidence of a reflection phase at the end.

"Any real computer must be able to deal with negative as well as positive.	Read text phase
Right. tstststststs. *Right, so.* *Positive sign.* *Negative sign.* *I seem to remember we did something...a little bit of this last year.* *Right, three wires, right.*	Orientate phase
Click on the button to give a digital value of -2.	Read text phase
-2. *That's on.*	Orientate phase
Put it on, right. *Em...right, so...right.* *OK.*	Analyse / Test concept phases
Right, so that was in.... *Right, so that's decimal values.* *Right, OK.* *Right, reading the next bit.·"*	Reflection phase

Student 2 (time spent on screen – 60sec.)

Student 2 spent less time on this screen that 5 out of 6 of the others, although he clearly moved through all phases of the predicted model, with the exception of a reflection phase. He demonstrated a particularly distinct orientation phase prior to his analysis and testing phases. It would be reasonable to suggest that his confidence in the topic negated the need for a reflection phase in this instance.

"Negative numbers.	Read text phase
Right, OK. *Let's move on.*	Orientate phase
Any real computer must be able to deal with negative numbers as well as positive. *Right, left most digit zero plus +ve sign.*	Read text phase

So 001 equals...plus 01 equals plus 1 decimal. *Right, left most digit, v sign 101 minus 01 is -1 decimal.*	Read text phase
Ok. *So click on the buttons to give a decimal value of -2.* *So I'm working in binary, binary.* *So if I want -1...so I want..oh right, OK.*	Orientate phase
So, just turn that one off. *Put that one on."*	Analyse / Test concept phases

Student 3 (time spent on screen – 88sec.)

Student 3 perhaps complied with the predicted model most rigorously out of the sample, with clear transitions through each of the model phases, including a degree of observed reflection at the end after the correct answer had been achieved. The conclusion to his verbalising however appeared to indicate that he did not perhaps fully understand the concept before moving on.

"Sign and magnitudes.	Read text phase
I don't think I've had a grasp of them, right. *I don't think I've grasped the hexadecimal and the binary.*	Reflection phase
Right, sign and magnitude represen... *Any real computer must be able to deal with negative numbers as well as positive.* *One way to represent a positive and a negative number is to use the leftmost bit to indicate the sign.* *E.g. the leftmost digit zero is positive, oh no.* *The leftmost digit zero is positive sign...°zero..plus 1.* *And the leftmost digit is a negative sign 101, right.* *(inaudible).*	Read text phase
°Eh, leftmost digit is zero..001 is positive. *-1, right.* *Click on the buttons to give a decimal value of -2.* *Now do I want to work that out and then do it, or*	Orientate phase

do I just press the buttons and I get there by default because that changes.
Yeah, well I got there by default right, so how would would they, how would I have got there?
-1 is on, so that's -1.
There was a positive."

Analyse / Test concept phases

Reflection phase

Student 4 (time spent on screen – 160sec.)

Student 4 spent more time on this screen that any other by a considerable margin. He was observed to have had some difficulty with the user interface, as he attempted to click on text and numbers to initiate interaction instead of the buttons on the screen, even though he'd already completed a previous screen which followed the same format. This, along with his audible sigh at the start, and part of the way through the module may imply a lack of motivation on his part by this stage.

His procedural pattern was interesting compared to the other students as he appeared to largely stay within the orientation phase, although some conceptual analysis was evident from screen capture. This seemed to be down to his understanding of the interaction required with the interface conflicting with his analysis of the concept, resulting in his resorting to trial and error to achieve a final answer with little or no reflection on where it came from. In this regard it has to be said that he failed to comply with the procedural model.

"(Sighs) Sign and magnitude representation.
Any real computer must be able to deal with negative numbers as well as positive.
One way to represent +ve and -ve numbers is to use the leftmost bit to indicate sign.
OK.
Click on the values to give an example of minus -2.
(Sighs) pmpmpmpmpmpmmmmmmm, -2.
Well, click on the values, right that would be on.
Uhuh, on, how do you get the negative to go on?

Read text phase

Orientate phase

Read text phase

Orientate phase

Oh, no wait a minute, well that would be 4 then.

Right, 4 with that off.

How are we getting this?

Oh, I see, right.

-3.

What am I looking for, minus what?

-2.

Off.

Hahahaha.

On.

On.

Plus 2 decimal.

Plus 1 decimal.

Minus decimal."

Analyse concept phase
Orientate phase
Orientate phase

Student 5 (time spent on screen – 40sec.)

Student 5 spent the least amount of time on the screen and both observation and screen capture indicated that he arrived at the correct answer by accident. This is borne out in his verbal protocol and screen capture which showed no evidence of analysis or testing phases and no evidence of reflection. His approach at this stage of the package appeared to very surface and goal orientated, where he simply wanted to move on to the next page and get through the package as fast as possible, with little concern for his understanding of the concepts covered.

"Just reading the first page about sign and

magnitude representation.

Its explaining that computers must be both

negative numbers as well as positive numbers.

I'm just gonna click on the hexadecimal value...

I actually got that one correct.

Onto the next page."

Read text phase
Orientate phase

Student 6 (time spent on screen – 69sec.)

Student 6 seemed confident throughout this screen, progressing through the *'read text'*, *'orientate'*, *'analyse'* and *'test concept'* phases and relating the content of the screen to her own prior knowledge. She chose to rehearse the problem by attempting to find the solution for another number before repeating the analysis and testing phases to arrive at the correct answer. In terms of her compliance with the procedural model, she clearly moved through the predicted phases, with the exception of any discernible reflection phase due to her confidence in the concept covered.

Transcript	Phase
"Just reading through the instructions just now.	Read text phase
Again, this is kind of sounding familiar from Calum's stuff, Calum's stuff in em second year.	Orientate phase
I'm trying to get -1. Switch that off, switch that on. That will give us the answer -2.	Analyse / Test concept phases

Student 7 (time spent on screen – 117sec.)

Like student 4, student 7 demonstrated evidence of becoming de-motivated with the package, sighing a number of times during the screen. He once again devoted a considerable period of time to the verbatim reading and reviewing of the screen text, although the fragmented structure of his verbalising would indicate that he may have been skimming the text at this stage. He was observed to have entered an orientation phase before attempting to interact with the package, although observational data would indicate that he used a trial and error approach in finally arriving at the solution. Evidence from screen capture indicated that he engaged both analysis and testing phases before returning to the orientation phase in preparation for a further testing phase. There was however no evidence of further analysis taking place before he achieved the correct answer through trial and error. There was some evidence of reflection before he moved on to the next screen.

Transcript	Phase
"(Sighs) Any real computer must be able to deal with negative as well as positive. One way to represent negative and positive numbers is to use the leftmost bit to indicate sign, leftmost bit to indicate sign. E.g. leftmost digit 0 as positive sign 001 equals plus 01, plus 1 in decimal. Leftmost digit 1 as minus sign 101 equals 0...right(sighs).	Read text phase

Transcript	Phase
Any real computer must be able to deal with negative	Return loop
as well as positive. *One way to represent negative and positive numbers is to use the leftmost bit to indicate sign.* *E.g. leftmost digit 0 as positive sign 001 equals plus 01, equals plus 1 in decimal.* *Leftmost digit 1 as negative sign 101 equals negative 01.*	Read text phase
Right. *Plus 1 in decimal, minus 1 in decimal.* *Three wires.* *Binary.* *Digital.* *Click on the buttons to give a decimal value of minus 2.*	Read text phase
Which was...	Orientate phase
Leftmost digit 0 is positive sign 001 equals plus 1 in decimal.	Analyse / Test concept phases
So on, on and off (sighs).	Orientate phase
On, on.	Test concept
Right."	Reflection phase

6.10.1.4. Procedural Model 4 – Screens Requiring Calculation

The final procedural model (Figure 30) was developed for screens that required a combination of calculation and data entry into the package. The main structure of the model is the same as procedural model 3, with the addition of a calculation phase. This was intended to supplement the analysis phase, and may have entailed the use of paper and electronic calculators, which were supplied, or a toolbox facility, which included specialist calculators and tables embedded in the screen.

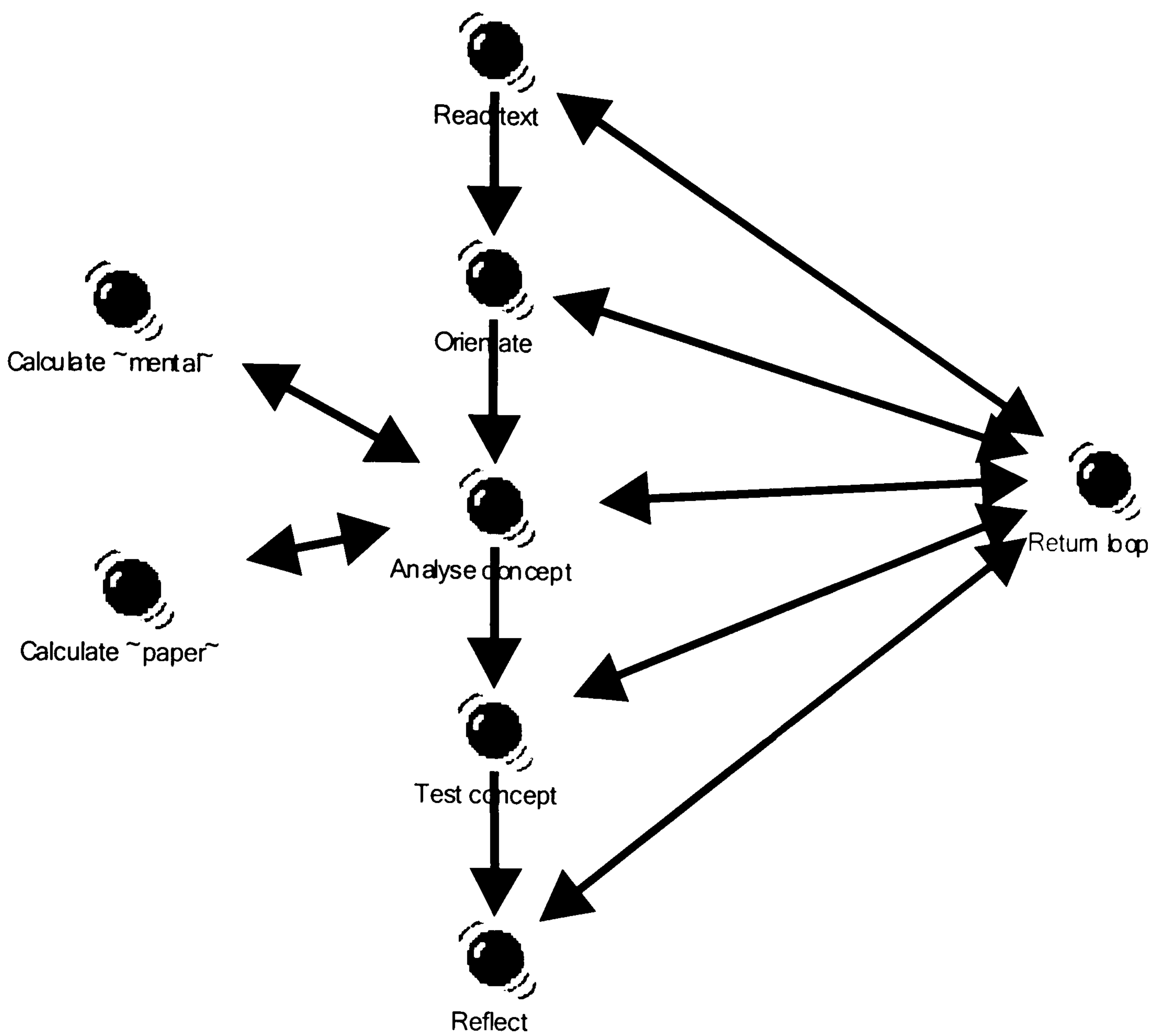


Figure 30 – Procedural Model 4

6.10.1.4.1. Introduction – Binary Numbers Screen 1.2.6

Screen 1.2.6 required the user to use the conceptual knowledge obtained from the preceding screen to answer a calculation question on binary addition. The task in this instance was to add the binary numbers 0110 and 0111. The expected correct answer would be 1011. Figure 31 shows the composition of the screen, including the data entry window and the binary calculator from the toolbox facility in use.

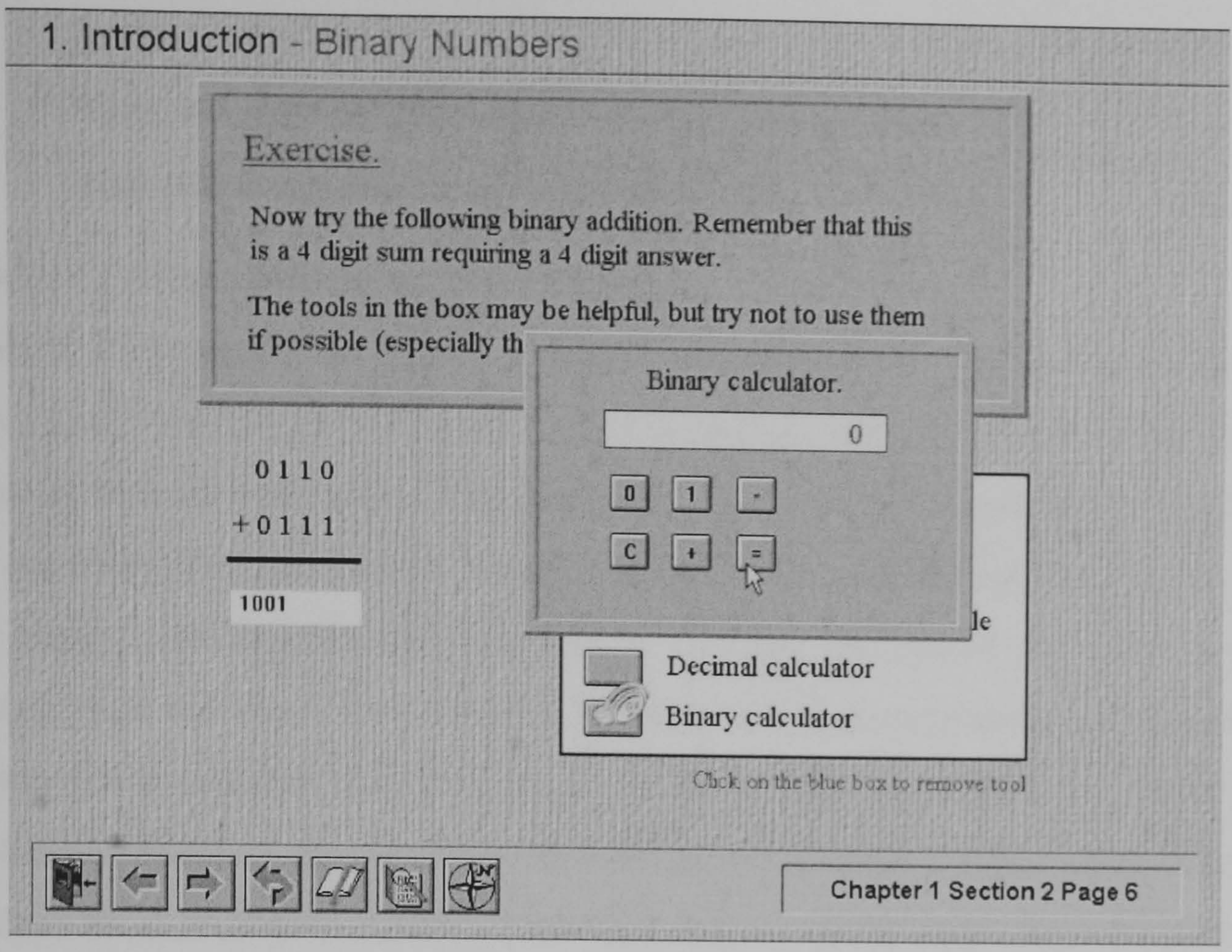


Figure 31

Student 1 (time spent on screen – 35sec.)

Student 1 spent considerably less time on this screen than any of the others, although his verbal protocol clearly indicates his fulfilment of the predicted model, with mental calculation being used at the '*calculate*' phase in preference to the paper and pen which had been provided. Although the student achieved the correct answer through mental calculation, it was observed that he failed to validate the answer by hitting the 'enter' or 'return' key on the keyboard and therefore had no means of knowing if his answer was in fact correct. This particular student went through the entire package without validating a single answer which may indicate a lack of reflective behaviour and a surface approach to his use of the package which was very goal driven.

"Right, now they're asking me to do an addition.
Emmm..4 digits...requiring a 4 digit answer.
Try not to use them if possible, especially the calculators.
Right.
So it's 1...

Read text phase
Orientate phase
Analyse concept phase

So it's 1101.

Right, the reason I did it that way was I worked out what was in my head and I just added it up."

Test concept phase
Reflection phase

Student 2 (time spent on screen – 154sec.)

Student 2's approach to the calculation screen was interesting in that he almost immediately moved to brief analysis and testing phases which culminated in the input of an incorrect answer. This prompted his use of the binary calculator from the on-screen toolbox facility. After some difficulty in understanding how to use the binary calculator he used the tool to compare his answer with the correct answer from the binary calculator. Since no actual conceptual analysis took place during his interaction with the toolbox facility, thus was coded as part of his '*orientate*' phase. It appeared that the toolbox provided invaluable support for the student as a reflective tool that allowed him to work backwards to gain an understanding of the concept being tested via the '*reflection*' phase. His method of inputting data into the package caused him some difficulty, as he tended to input data in reverse, i.e. rather than inputting the correct answer (1101) as 1-1-0-1 he input it as 1-0-1-1, although his intention was to input 1101. This will be discussed further during the validation of his verbal protocol for the next screen example (1.3.5), where the learning process broke down almost completely due to his inability to input data correctly. With regard to the predicted procedural model, it can be seen that he complied with the model during his first attempt at the question. During subsequent attempts however (after his initiation of a return loop) he entered a prolonged orientation phase where he acquainted himself with some of the facilities within the toolbox before a final reflection phase where he attempted to gain an understanding of the concept through working backwards from the correct answer.

"Now try the following binary addition, that this is a 4 digit sum requiring a 4 digit answer.

Right, so 0 plus 1 equals 0.

Now, does this work backwards or...(inaudible), oh no, it'll do,

1001.

Sooo...a binary calculator.

Read text phase
Orientate phase
Analyse concept phase
Test concept phase

Equals..OK, 1001.	Return loop
Right, OK, just ignore that. *(Inaudible).* *So, I'm getting that, aahh, right, compare it.* *Well, it should have said.* *Right, binary calculator.* *Zero, right...okedoke.* *Why's this not working?* *Ah, right, 0110 plus 0111, equals, not my answer.*	Orientate phase
Ok..where'd I go wrong? *0 and 1 equals 1.* *1 and 0 (means 1 presumably) equals, ah, 0 carry the 1.* *Right.* *Carry the 1,giving you 1, 0, 0 carry the 1.* *Right...see where I went wrong.* *So, that would be 0, 1, no hold on, 1(sighs).* *So it's 1, 0, 0 carry the 1.* *Me thinks, correct-."*	Reflection phase

Student 3 (time spent on screen – 186sec.)

Student 3 immediately opted to work on paper for calculation purposes during the analysis phase of the procedure. In the first instance, this resulted in his inputting an incorrect answer (0101), which in turn instigated a period of reflection, where he worked between his paper notes and the screen followed by the initiation of a return loop. After a period of reflection he chose to use the binary calculator for a further calculation and analysis phase, although he was observed to input information incorrectly into the calculator leading to a consequent breakdown in his understanding of the concept and a further incorrect answer of 1001. This appeared to emanate from his lack of understanding of the carry system. He was also observed to have switched between decimal and binary language conventions, referring to the number two in binary (10) as ten and he exhibited evidence of frustration with his inability to achieve a correct answer.

Upon the initiation of another return loop, the student entered another calculation and analysis phase, with the support of the binary addition table from the on-screen toolbox. He eventually decided to leave the screen without obtaining a correct answer or any period of reflection.

His inability to use the binary calculator as a reflective tool, as was also the case with student 2, appeared to be largely responsible for his inability to make progress in his understanding of the concept. This may have contributed to his frustration towards the end of his time on the screen.

"Introduction, exercise. *Now try the following binary addition.* *Remember this is a four digit sum requiring a digit answer.*	Read text phase
Right, 0 plus 1, so that's a 1. *1 plus 1...right, that gives me a zero and carry 1.* *1 plus 1 gives me a zero, carry 1.* *And zero plus zero is zero.*	Analyse concept phase
Oh, so this is 0101.	Test concept phase
(Sighs) Right.	Reflection phase
How's that then?	Return loop
1 plus 0, 1 plus 0 is 1. *1 plus 1 is 0..carry 1.* *1 plus 1 is 0, carry 1.* *1 plus 1 is 0.* *Is 1.* *Right, try this guy (binary calculator).* *Zero plus 1.*	Analyse concept phase
Right, we know that should be 1, right. *That's fine.*	Orientate phase
Right, 1 plus 1...is ten (10)..so it would be zero, carry 1. *1 plus 1 is ten (10).*	Analyse concept phase
Aaach.	Test concept phase
Right.	Return loop

°zero, zero.

So is that that one then?

Right.

(Sighs).

Try this thing here right (binary addition table).

Take that away.

Right, one more go, right.

Zero, right, plus 1 is 1.

Right, I had that.

1 plus 1 is ten (10), so put in your zero, carry the 1.

1 plus 1 is ten (10).

No.

Nope.

No understanding that at all, so I'll move on."

Analyse concept phase

Student 4 (time spent on screen – 390sec.)

Student 4 spent more time on this screen that any other. It was observed that he was having considerable difficulty with inputting data into the on-screen window. This led to a complete breakdown in his conceptual understanding, from what appeared to be a correct understanding, to one which was defined by his incorrect method of data entry into the screen. This began with his positioning the cursor inside the data input window under the digits being calculated in each case before performing the calculation, leading to the software refusing data entry, although it did appear that he was working towards a correct answer first time around. Because he was observed to be breaking the problem into manageable chunks and inputting data to the system in chunks, his ability to process the calculation steps was being impaired by his need to reverse the order of his answer for input to the screen in chunks. The data input window did not lend itself to a step by step approach, as it was designed to accept only a final answer.

After prompting from me, he proceeded to carry out the calculation backwards to meet what he perceived to be the demands of the input window. This led to further confusion with the carry system. Analysis of his verbal protocol indicates a lack of confidence and frustration in his inability to understand the concept, which emanated from the problems that he encountered with the user interface. Even though he initiated more than one return loop, where he broke the analysis and calculation phases into discrete processing chunks followed by periods of reflection, he finally left the screen having essentially 'unlearned' the concept.

"Exercise, now try the following binary addition. *Remember that this is a four digit sum requiring a four digit answer.* *The tools in the box may be helpful, but try not to use them if possible.*	Read text phase
Right, 0+.....is 1. *Can you move this along?*	Orientate phase
Sssssssssssssssttt 1...0, carry 1....and that would be 101. *1 and 1 is 0, carry 1 and 1...that will be 1 again.* *Come on tae...* *Oh no, is it not allowing me to put the zero in?* *Least significant digit first.* *1+1, I'm working from the wrong way.* *1 and 1 is 0...carry 1.* *1...0...what do we do now?*	Analyse concept phase
Least significant digit first!	Read text phase
Which is that! *That will be one.* *That will be zero, carry one.* *That would be 10 carry 1.* *1.*	Analyse concept phase
Oh, I see. *It won't let me type anything in here (to researcher).* *Is that cos I'm going backwards with it?* *(prompted by researcher)* *Right.* *(prompted by researcher)* *Aye, well that's, that's the problem, cos I'm starting*	Orientate phase

from over here. *Right, OK.*	Orientate phase
That's tstststststststs, so the last number was, is going to be eh 1. *Eh, the next number is going to be, eh 10 an....ahahah.. 1, it's also gonna be a 1, ehhhhhhhhh......that's*	Analyse concept phase
gonna be one, one one...carry one, carry one, zero. *Oh no.*	Test concept phase
Oh I see.	Orientate phase
And that has to be...one. *Binary addition table.* *Binary-dec, carry one.* *Ah, decimal calculator.* *Binary calculator.* *Right, tfftfftff...1 and 0 is 1.* *1 and 1 is 0, carry 1.* *So...the first number is definitely a one.* *The second number is definitely a zero.* *The third number is 1 and 1...is zero carry one, plus one...which again is a zero...zero and zero and we're*	Analyse concept phase
carrying one, which would be a one, awwwwwhahahaha, *I'm guessing.*	Test concept phase
Pmmpmmpmmpmm, four digit answer. *Right that's definately right, that's definately right,*	Orientate phase
carry one one one one. *Well, the only thing that I can think that can possibly be (prompted to speak more clearly) sorry...right.* *Right, the only thing that it can possibly be is that I'm getting that completely...wrong...and one and one and zero, carry one is still one.*	Analyse concept phase
So...eh, OK, right.	Test concept phase
So one and one and zero plus one...is still one. *OK, take your word for it."*	Reflection phase

Student 5 (time spent on screen – 64sec.)

Student 5 spent a considerable amount of time reviewing the introductory text before deciding to use the toolbox facility. Both the screen capture and observational data confirmed however that he failed to open any of the facilities inside the toolbox and instead quickly left the screen without attempting the problem. The assumption made was that he lacked confidence in his understanding of the concept, and perhaps his fear of failure may have contributed to his moving on, although in terms of his fulfilment of the predicted model, he did not, in fact, move beyond the orientation phase before leaving.

"Eh, still on binary numbers. *I'm just reading the exercise.*	Read text phase
Again, this page has came up...that there's a little *clue about eh, there's tools in a, a toolbox you can,* *eh, use, use to assist the adding of the binary numbers.* *So I'm having a look in that toolbox to see what is* *available.* *Again the instructions in this page is quite clear,* *but my personal interpretation of adding the numbers,* *eh, I'm not sure how to do it, so I'm just going to* *move on to the next page."*	Orientate phase

Student 6 (time spent on screen – 543sec.)

Student 6 was the only one of the seven who elected to initiate a return loop to a previous screen (1.2.5) as a means of consolidating her understanding of the concept under test. Her time spent on the screen, at 546 seconds was considerably more than any of the others and reflected her approach to the question. Her general approach to the screen was to immediately use pen and paper at the end of her reading of the introductory text. The analysis phase was almost entirely carried out through pen and paper before returning to the package to test her answer. This was followed by the use of a combination of paper and the on-screen toolbox facility for subsequent loops.

This student again had a little difficulty in understanding what was being asked of her in the question and input a decimal number (8421), as her first answer to the question. This was interesting since her verbalising was all carried out in binary and the user interface had not requested an answer in decimal. In line with other students, upon receipt of a *'try again'* response to her incorrect answer, she immediately chose to initiate a return loop, with no reflection phase apparent. There was also further evidence of inappropriate cross-over between decimal and binary language, where she described the number two in binary as ten (10).

The ability to understand and manipulate binary numbers, and in particular, the carry system, again appeared to cause the greatest problem for this student, as was the case for a number of others. Although she took more paper notes than any other, the lack of structure to her note-taking resulted in their limited value in supporting her through the analytical phase. This placed greater demand on her short-term recall during the analysis and testing phases. An example of this arose when she attempted to use recall from the previous animation (screen 1.2.5) to answer the question,

> *The least significant number that it was talking about on the last page.*
> *Em, adding them together is 01 and getting zero, which I think's right.*

Her verbal protocol indicated that she had applied theory incorrectly from the previous screen resulting in a subsequent breakdown in her understanding due to her inability to retain the information provided through the previous animation. Once again, she appeared to get bogged down with the carry system in binary, leading to her initiation of a couple of return loops. Like most of the other students, she chose not to convert between binary and decimal as one would have perhaps expected for a problem of this nature.

> *Eh, sorry, just em trying to work this out.*
> *Going through this top bit I've come up with the answer.*
> *I think would be 1111.*
> *I'm just trying to sort it out into the actual...em, the proper numbers.*
> *Not sure about this because em, in the first part you're adding 01, which you're getting 1.*
> *You're adding 11 together, you're getting 1.*

Analyse concept phase

You're carrying the 1 over. *Em..then you're adding 1 and 1 again to get 1, but you've already got that 1 carried over, so I'm not sure how...it's going to work out.* *Em...is that OK?* *(prompted by researcher)* *OK.*	Analyse concept phase
Adding this together, I think I've got it completely wrong (inaudible..laughs). *Wrong (laughs).* *Right, OK.*	Test concept phase
(Returns to screen 1.2.5)	Return loop
(Returns to screen 1.2.6) *Em...We were carrying over the 1 and had 1001 and that was equal to 9.* *Em...so I'm going to attempt this next question again.* *I've just sorted all these wee buttons.* *Seeing what they are.* *So...attempting this again.*	Orientate phase
Em, 01 is equal to 1. *11 is equal to ten.*	Analyse concept phase
and 1 again is equal to ten. *Oh.*	Test concept phase
Can't remember how to do this at all. *Just looking at this binary dec, sorry binary, binary decimal conversion, aahh, can't say that..conversion table.* *Em, see if that will help me.*	Orientate phase
At the moment I'm just...that previous one..em, on the last page..is 1001 is equal to 9. *I'm just going to see if I can work out how that was actually formed.* *Em.*	Analyse concept phase
(Returns to screen 1.2.5)	Return loop
(Returns to screen 1.2.6) *Em..still trying to work this out.* *Em..not really getting anywhere.*	Orientate phase

The least significant number that it was talking about on the last page. *Em, adding them together is 01 and getting zero, which I think's right.* *The 11, em, going by this binary addition table, if you add them together you get ten.* *Em..so you would be carrying the 1 over and you would be left with the zero.* *Em, the same for the next one.* *You've got the 11, plus the 1 that you're carrying over.* *Em.* *I'm not really sure what to do with that.* *Em.* *I tried before..the 11 giving you ten..and putting it through as, em..instead of zero and carrying the 1 over, having the 1 and carrying the 1 over.*	Analyse concept phase
Em, should leave you with 001. *Em.* *Nope.*	Test concept phase
What I did there; I had the two, the two zeros and the 1 that was then carried over before I'd em... *I'd put a 1 down, cos 1 was getting carried over.*	Analyse concept phase
But then I thought if maybe with the two zeros...em, I'd put...oh, there we go.	Test concept phase
Got the right answer there but I..instead of putting a zero in for the first number, having it as a 1, so that the right answer was 1101. *OK, next page.*	Reflection phase

Student 7 (time spent on screen – 131sec.)

Student 7 also chose to move directly to pen and paper for the analysis phase of the problem after reading the introductory text. He also initiated three return loops during his time on the screen, due to his input of a number of incorrect answers. The first two of these entailed a further analysis and calculation phase which was carried out on paper, with the second including a review of the demonstration animation on the previous screen prior to his inserting the correct answer on-screen.

Once again, this student's problems stemmed from a lack of understanding of the carry system in binary, although the use of a return loop to the previous screen did allow him to undertake a further analysis phase prior to his testing of the correct answer. Like some of the other students, he referred to the numbers 10 (2) in binary as ten in decimal, although he also chose not to convert each number separately to their decimal equivalent as a means of problem solving.

"Now try the following binary addition. Remember *that this is a four digit sum requiring a four digit answer.* *The tools in the box may be helpful but try not to use* *them if possible, especially the calculators, alright.*	Read text phase
0 plus 1 is 1, which will be...1 plus 1 is 0 carry 1, *is 0...but does carry, does that carry forward the now?* *0110, 0111, which is 1, so carry 1...000...not sure your* *going to carry over there-...or 4 digit, which is 3, so* *it must be carried over which will be 1.*	Analyse concept phase
(Sighs) 01, 0101. *Nope, huh God.*	Test concept phase
(mumbles), carries there.	Analyse concept phase
(Sighs)1001, which will be...nope, find it quite difficult-.	Test concept phase
Right.	Orientate phase
1 plus 1 is 10(ten)? *So that will be the carry coming over there.*	Analyse concept phase
So 0110 plus 0111 °equals 1 plus 10(ten)...and 01 *(sighs)...should be 0, 1101.*	Test concept phase
Yup. *Right, I think I've got the jist of that now- (sighs).* *So, it's actually carry 1 is just 10(ten), rather than carry 1.* *Well, try not to use them if possible. Right."*	Reflection phase

Interestingly, there was very little or no direct evidence of students converting the binary numbers given in the question to the more familiar decimal equivalents prior to manipulating through addition to achieve a correct answer. Most students appeared to suspend their knowledge of the decimal system and its relationship with the binary system, often becoming bogged down in the manipulation of binary addition and in particular the carry system.

6.10.1.4.2. Introduction – Hexadecimal Numbers Screen 1.3.5

The second screen chosen which conforms to procedural model 4 followed the same structure as screen 1.2.6 and highlighted some interesting issues, which arose during students' interaction with the screen. The screen itself built upon previous screens' discussion and demonstration of the hexadecimal number system and addition of hexadecimal numbers. The students were asked to add the hexadecimal numbers 1F3A and 30E2. Figure 32 shows the screen and demonstrates the conformity of structure with previous model 4 screens. In this case the hexadecimal table from the toolbox facility can be seen in use.

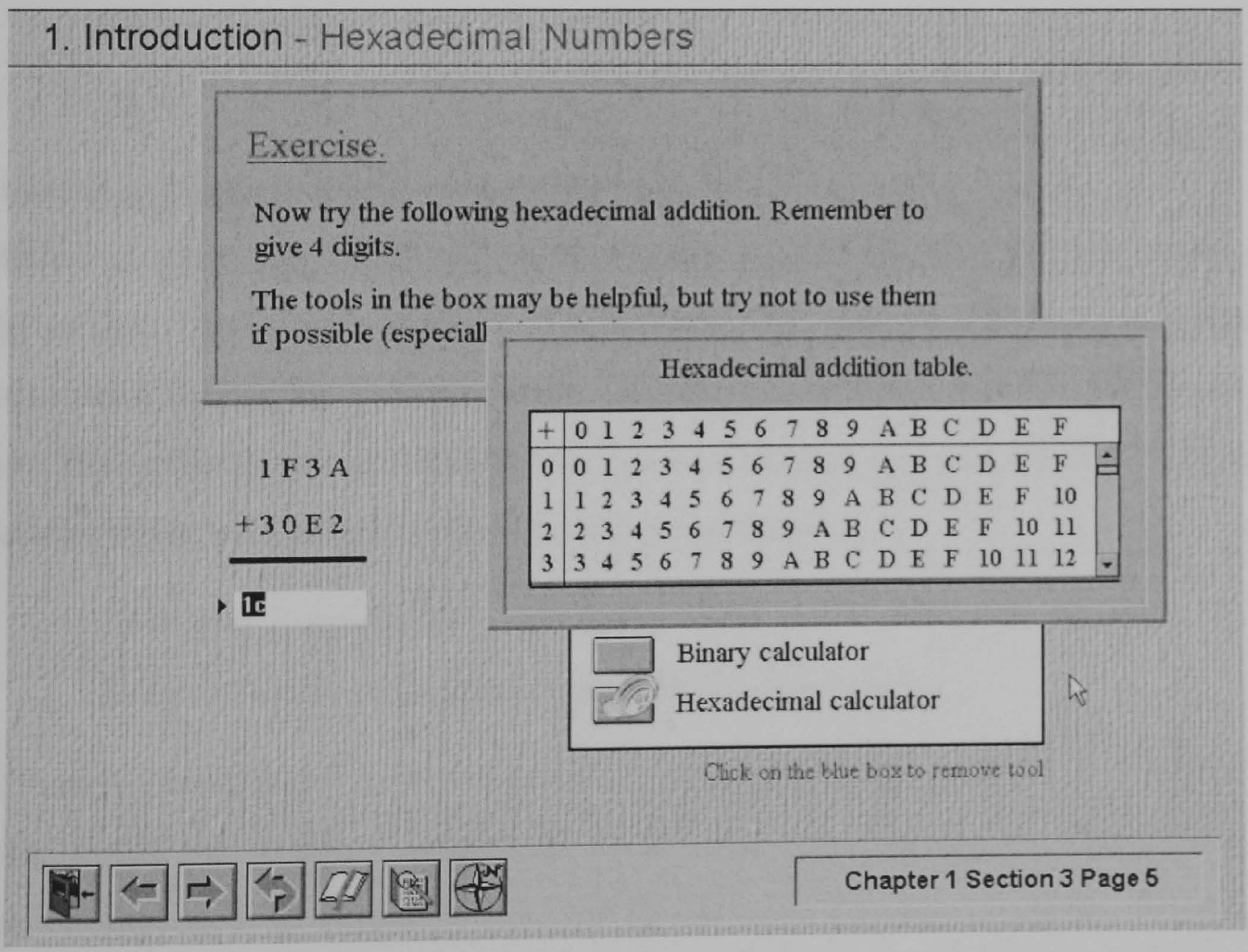
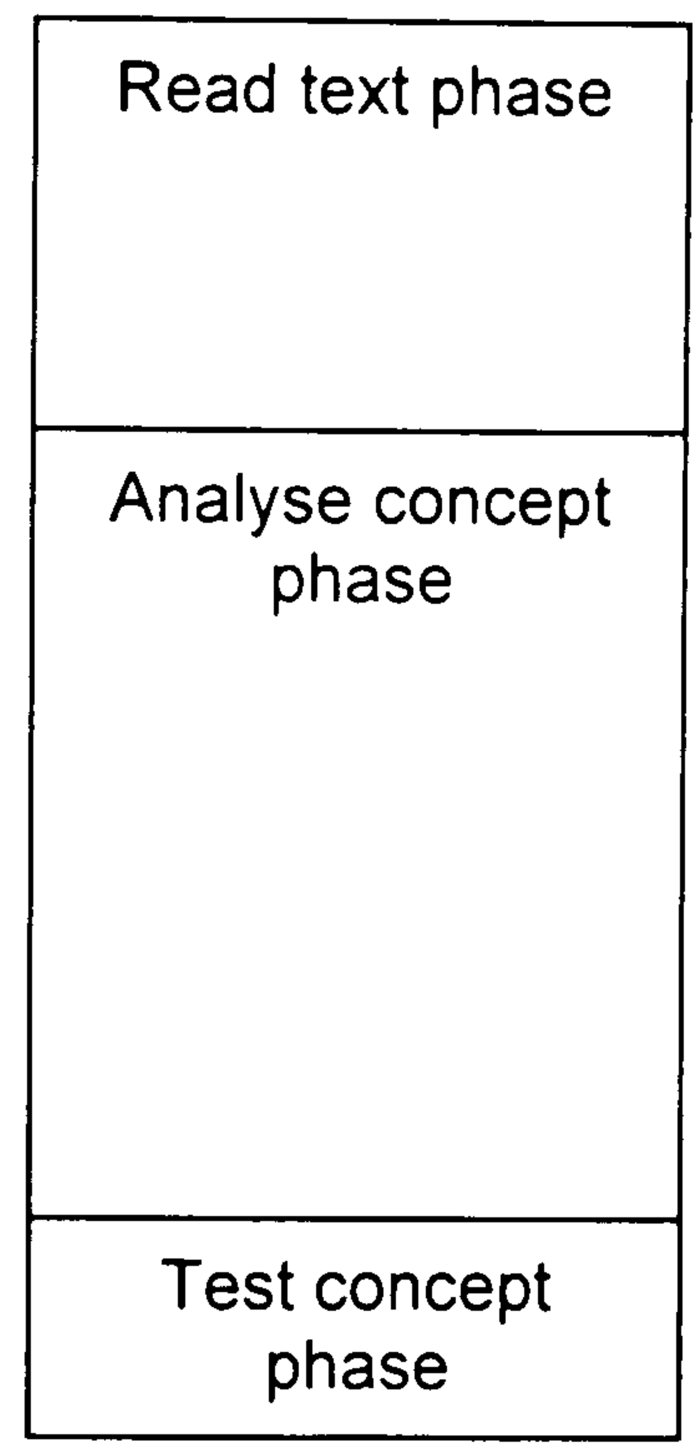


Figure 32

Student 1 (time spent on screen – 57sec.)

While student 1 followed the predicted model, with the exception of the reflection phase, he chose to employ mental calculation during the analysis phase in lieu of paper and arrived at an incorrect answer. His interaction with the package was again characterised by his lack of validation of answers, resulting in his leaving the screen after inputting an incorrect answer without any initiation of return loops or reflection. This is further evidenced by his minimal time spent on the screen compared with the other students.

> *"Right, try and add the following.*
> *1F3A.*
> *30E2.*
> *2 and A is...ten, twelve, twelve.*
> *C.*
> *E is 14..15, 16, 17.*
> *17 is 15 and 2..carry 1.*
> *This becomes a zero, carry 1.*
> *That becomes 5.*
> *502C."*



Student 2 (time spent on screen –787sec.)

Student 2 spent a considerably longer period of time on this screen than any of the others. His initial approach to the problem was to carry out a mental calculation during the analysis phase, after having read through the introductory text. His verbal protocol indicated an initial confusion between hexadecimal and decimal systems during his carrying out the calculation.

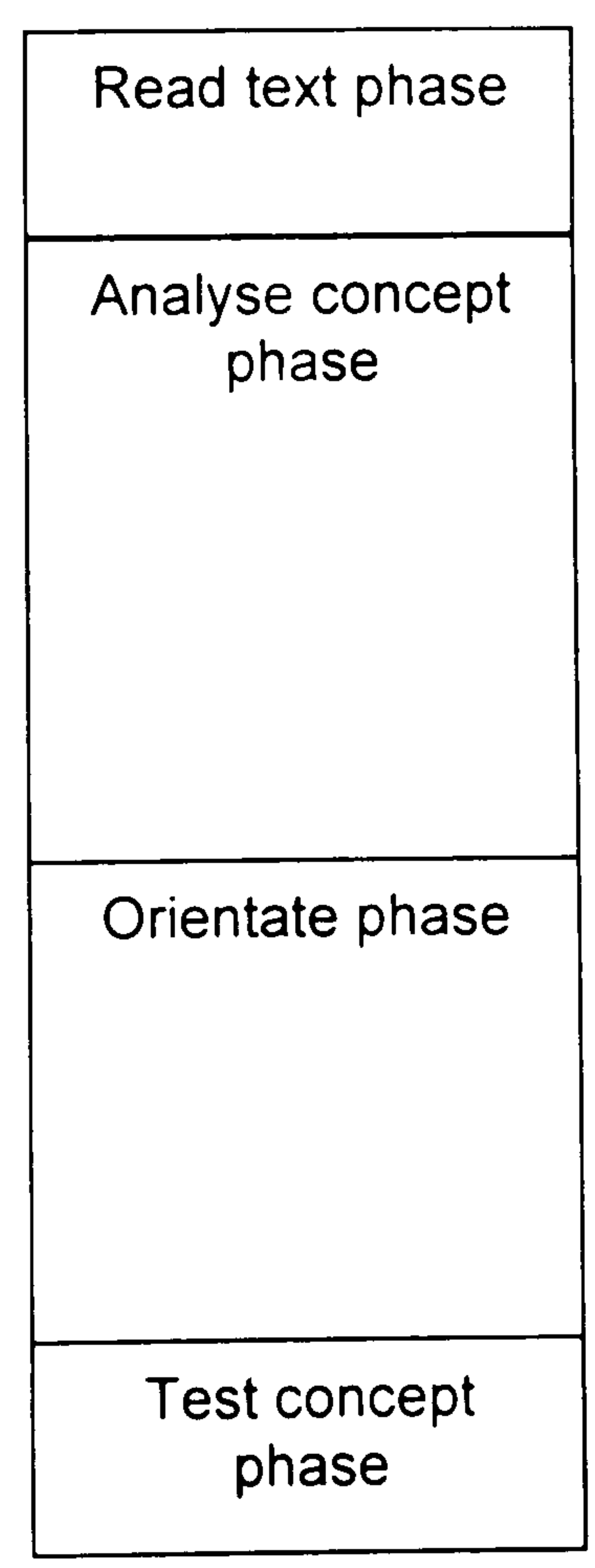
> *"Ten plus 2 equals 12.*
> *So does that mean we put 2 down and carry the ten?"*

Although he regarded it as '*cheating*' by referring to the hexadecimal addition table inside the toolbox in order to obtain an answer, it can be seen from his earlier approach to screen 1.2.6 that he used the tools to reflect and work backwards. This is evidenced in the additional time he spent on the problem until he was confident that he understood the concept. It was also interesting that although he had used the hexadecimal calculator inside the toolbox to get the correct answer of 501c, he chose not to enter this into the screen as his answer. Instead he entered a further analysis phase, where he attempted to answer the question without reference to the answer that he had just obtained through the calculator. After a number of return loops, at the orientation and analysis phases, he chose to return to the previous page for a number of further reviews of the demonstration animation.

Observation of his behaviour in general indicated a series of complete loops, with regards to the predicted model, including the reflection phase and incorporating the use of a number of resources including the toolbox and pen and paper. Once again, however there were indications through observation and his verbal protocol that the lack of structured notes from previous screens placed demands on his short-term recall that he could not meet, resulting in a lack of understanding of the hexadecimal number system and an inability to carry out basic manipulation using the system. This was particularly evident in his inability to grasp the carry system after reviewing the previous animation on a number of occasions.

Interestingly, he was only happy to insert the correct answer into the screen when he was happy that he understood the concept, even though he already knew the answer.

> *"Now try the following hexadecimal addition.*
> *Remember to give 4 digits.*
> *Right, so A equals ten.*
> *Ten plus 2 equals 12.*
> *So does that mean we put 2 down and carry the ten?*
> *Right, so if that's ten, carry the 2.*
> *Right.*
> *I'm going to cheat here.*
> *I'm going to use the hex addition table.*
> *(Laughs).*
> *No, calculator, I want the calculator.*
> *So, 1F3A plus 30(thirty)E2 gives me 501C, because..*
> *that's what you get.*



How?	Reflection phase
So A plus 2 is ten plus 2.	Analyse concept phase
Gives me 12.	
12, ah, nuts, aye.	
For some reason I'm stuck on the A and ten.	
Cos it only goes up to 16 for us.	
For some reason I thought it was going up to ten.	
Right, so A plus 2 is ten, so that equals E.	
Ah, right, so E.	
3 plus E, gives me F, G, H.	
Therefore carry it cos I've went over my 16.	
Right.	
Where's the hexadecimal table?	
So, if I'm going 3 plus E.	
E, F.	
Right.	
3 plus E..gives me a value of...10, 11, 12, 13, 14.	
14 plus 3..gives me 17.	
So that goes F.	
Right.	Orientate phase
Who said hexadecimal was easier.	
I prefer binary.	
3 plus E..gives me 17.	Analyse concept phase
So is that 10 carry the 7?	
Or 16 carry 1?	
Ah! 16 carry 1.	
That might be easier.	
Right.	
So F plus zero.	
Right, I'm starting to get confused here.	Test concept phase
1F3A plus 30E2 is 501C.	
Right, use the paper, work this out.	Orientate phase
Inaudible.	
1F3A.	Analyse concept phase

Right, so that's 10, that's 3. *F, 16, that's 1.* *30(thirty)E2, gives me 2E, equals 15.* *I think.* *Aye, 15.* *Zero, 3.*	Analyse concept phase
Right, so if I convert these into numbers, 1, 16, 3, 10 and add them..together or in actual letters, might be a wee bit easier.	Orientate phase
So 10 plus 2 gives me...12. *3 plus 15...E.* *How do you get this?* *E equals..10, 11, 12, 13, 14 not 15.* *Ah..right..14.* *That's 15.* *Right, so 3 plus 14 is 17.* *15 plus zero equals 15.* *1 plus 3 equals 4.*	Analyse concept phase
So what's F, so it's 12 equals C, 17, doesn't happen, so...what is it I do there again? *Carry it?* *Inaudible, 1.* *Right, need to go back a page.* *Not understanding this."*	Reflection phase
(Returns to screen 1.3.4)	Return loop
(Returns to screen 1.3.5) "*Hopefully try and answer this.*	Orientate phase
So A plus 2 equals, what did I say, C. *3 plus E equals 1.* *Ah.* *I'm just not getting this.* *F and zero.* *Hex conversion table.* *3 plus E...equals 14.*	Analyse concept phase

Transcript	Phase
14 plus 3 equals 17.	Analyse concept phase
So is that zero carry the 1, or...sighs.	
What do they get?	
Right back to the calculator.	Return loop
1FCA plus 30E2 gives me 501C.	Test concept phase
Right so 3 and E.	
How do we get 1 from 3 and E?	Analyse concept phase
So 3E gives me 1.	
How?	
How does that give me 1?	
Then I've got..F..F zero, gives me zero.	
And 1 and 3 gives me 5.	
So obviously something's being carried over there.	
Right, hex addition table.	
This looks more...	
Sighs.	
Right, E plus 3..1-, 2, 3.	
2, 3.	
Right, OK, maybe that's why you get 1.	
F and zero..F plus nothing...gives you nothing.	
Or just F.	
Lost my pen. There it's.	
Prompted.	
Laughs.	
I'm just not understanding this hexadecimal.	
I'm losing it!	
A plus 2.	
I can see where they're getting C.	
3 plus E..I'm guessing E equals 1...2, 3.	Reflection phase
Or am I just finding different paths to get the answers because I know the answer?	
F and zero...maybe if it was F and O, I might understand it.	
Right, so F and zero should give me zero.	

How? *Don't know.* *F plus zero.* *You'd think that F and zero, F would still be the same.* *Or am I just getting lost in normal mathematics?*	Reflection phase
Zero carry the 1.	Analyse concept phase
(Sighs) No, it's not happening. *Laughs..I'm staring, I'm getting lost, getting more confused.*	Reflection phase
Right, I'm going to go back and try to understand this addition."	Return loop
"1F3A. *501C.*	Test concept phase
How? *Right, A and 2, I get that.* *I know how to get the C.* *3 and E...I think I know how you get that.* *I know how you get the 1.* *F and zero.*	Analyse concept phase
Aaaahhh. *OK.* *No.*	Reflection phase
No, I'm just losing it here.	Return loop
Hex addition table. *How does that work?* *There's no lines to the...oh, right-.* *OK, this might be handy.*	Orientate phase
3 plus E...gives me B. *OK, not working.* *3 plus E gives me 11.*	Analyse concept phase
Aaaahhh, right. *Right, that addition table would have been handy..if I'd realised it was there.*	Reflection phase

Right-. *OK.*	Reflection phase
I understand this now.	Return loop
Right, so A plus 2..so, gives me 12. *I'll just double check this with the addition table.* *A plus 2, gives me C.* *OK, which is 12, my way.* *3 plus E..3 plus E..gives me 11.* *Hence the 1 carry the 1 over.* *So 1 plus F gives you 10...carry the 1 over.* *Aaaahhh, 5.*	Analyse concept phase
501C. *Yep. Not that that probably took about half an hour."*	Test concept phase

Student 3 (time spent on screen – 280sec.)

Evidence from observation and screen capture highlighted student 3's initial problems with the user interface when it came to enter data on-screen. Due to the 'chunking' approach that he took during the calculation and analysis phases, he chose to analyse and input results to each pair of digits making up the addition one at a time. This led to his processing of data in reverse, giving him an on-screen answer of c105 in lieu of 501c. Although he was applying theory correctly during the calculation and analysis phases, this error led to him effectively 'unlearning' the concept, as the negative feedback from the software instigated a return loop. This was similar to the experience of student 4 during screen 1.2.6 discussed previously. The lack of explicit guidance on how to use the package proved problematic in this instance, although the evidence discussed previously showed that the student had spent little time on instructional screens.

With regard to his conformance with the predicted model, it was clear through his verbal protocol and observation that the model was being implemented, including a reflection phase.

"A plus 2. *Right, A plus 2 is 12.* *12.*	Analyse concept phase

Right, so, A, B, is that a C?	Analyse concept phase
(inaudible)ten.	
First one's C. (inputting data in reverse)	
Right, 3 plus E.	
E is 15, so 3 plus E is eh, 18.	
That must be wrong, so that will be..carry 1, so that's 8.	
Carry 1, F plus 1..no.	
F plus 1...is 16, so that would be zero carry 1.	
1 plus 3 is 4 and 1 is 5.	
That's probably way out.	Test concept phase
Right.	Reflection phase
(Sighs) I think I understand maybe half the principles of this, but not it all.	
Right.	
Not it all.	
Right, A, A plus 2, is C, well I had that.	Return loop
Right, I had that.	Analyse concept phase
3, 3 plus...right 3 plus E was 11.	
So that's 1 carry 1.	
° 1 carry 1.	
F plus 1.	
F plus 1 was ten.	
It was zero carry 1.	
So that would be 2..that's 5.	
Is that not..(prompted), right, so try enter.	Test concept phase
Right·.	Return loop
F plus, A plus 2.	Analyse concept phase
A, A plus 2 is C, right, right.	
3 plus E is 11.	
Now what represents 11?	
This is where we're falling down.	
It's ten plus 1.	
You put a one in there? ...Carry 1.	

F plus 1 is zero..carry 1. *5, that's wrong again, but.*	Test concept phase
C, I'll click that, get rid of that.	Return loop
I'll try this. *A plus 2 equals, right I was happy with that.* *I had that, right.* *Cancel.* *3 plus E, that came to 11, right.* *Right, that was fine.* *1...* *F, F plus zero equals F.* *And F equals 15 or something like that..16, isn't it?* *A, B, C, D, E, F.* *°So that would be F.* *So that was C3F.* *Right, cancel.* *1 plus 3 equals 4.* *Right.* *Right, click that.* *Click on that.*	Analyse concept phase
C3F4, right we'll (laughs).	Test concept phase
Now I wonder if it's capital conscious or whatever? *(Laughs)* *Right, we'll go on."*	Orientate phase

Student 4 (time spent on screen – 120sec.)

Observation of student 4 indicated that by this stage in the module he had become frustrated and de-motivated. This was clear from his observation log notes for the previous screen (1.3.4), which was intended to provide the theoretical support to enable him to undertake the question on this screen.

"Becoming fidgety and frustrated."

"No real attention during animation."

His approach to the question was to turn to the hexadecimal addition table and subsequently the hexadecimal calculator inside the toolbox almost immediately, after attempting some mental calculation. His verbal protocol for the screen indicated that his prime motivation was to achieve a correct answer that would allow him to move on to the next screen irrespective of whether he had reached a conceptual understanding or not, and highlights a truncated analysis phase with little conceptual reflection evident at the end. He alluded to his perceived difficulty with the theory before moving on to the next page,

> *"Given that trying to do that in your head, with my knowledge is virtually impossible."*

This statement once again highlights the student's inability to transfer learning through short-term recall from previous screens to the active one. Again, he chose not to take supplementary notes during his use of the package. It also highlighted the students' general reluctance to initiate appropriate return loops and return to previous learning as and when required.

> *"OK, Hex addition table.*
> *Let's try it first of all and see what we can do.*
> *A would be..11...zero and zero and zeeeeee, no*
> *sorry, 9, 10 and 2 would be 12.*
> *A've got no chance of doing that.*
> *And that's just, hexadecimal calculator.*
> *1F (sighs) (unclear).*
> *3A plus 3, zero, E...2 equals five 0...equals....501C.*
> *(unclear)(sighs) 501C.*
> *My comment on that is that obviously*
> *hexadecimal, hexadecimal calculator is invaluable.*
> *Given that trying to do that in your head, with my*
> *knowledge is virtually impossible."*

Orientate phase
Analyse concept phase
Test concept phase
Reflection phase

Student 5 (time spent on screen – 70sec.)

Student 5 again appeared to lack confidence in his ability to tackle the question. He spent most of his time on screen familiarising himself with the hexadecimal addition table inside the toolbox, before leaving the screen without attempting the question. In terms of his conformance with the predicted model, analysis of his verbal protocol indicated that he did not move beyond the orientation phase.

At this stage, his strategy centred on his need to progress through the module as quickly as possible, with little progression through the predicted model evident during this type of screen. Observational evidence from the previous page indicated that he was struggling with the pace of the animated elements, and was therefore having difficulty in processing the theoretical information required to tackle the question. Rather that initiate a return loop and review these elements, he invariably chose to move on, providing himself with little of the theoretical support necessary to complete the question.

> *"It's an exercise this one.*
> *There's a toolbox to assist...(mumbles...)assistance from the toolbox.*
> *I'm just opening the hexadecimal addition table.*
> *Just gonna move onto the next page."*

Read text phase
Orientate phase

Student 6 (time spent on screen – 282sec.)

Student 6 was the only one who was observed to have used her own paper notes from previous screens to support her through the analysis phase of this screen.

> *"Look at what I wrote down earlier from the previous ones."*

Her observation log indicated that because of the structure of the package, she had predicted that a question screen would follow from the animated demonstration screen (1.3.4), and that notes would provide useful support in tackling the question screen.

> *"Taking down notes during animation to use in answering future questions – anticipating format – example to question."*

Although she had input an incorrect answer in the first instance, she followed the predicted model and after a clear reflection phase, initiated a return loop once she had received feedback from the software. Her verbalising indicated that she had little difficulty in resolving the problem second time around, with the support of her own notes. This further highlighted the problems of short-term recall associated with other students' approach to the question, based on their processing and retention of theoretical information from demonstration screens as a precursor to question screens.

"·Em, just reading through these instructions.	Read text phase
So...1F3A...30E2. *A was equal to ten.* *Look at what I wrote down earlier from the previous ones.* *Eh, 12 would be equal to C.* *Em 3 plus E, well E is 14.* *14, 15, 16, 17..equal to 1.* *So you're carrying over two.* *Em.* *F is 15.* *If that was F which is 15 plus the two that was carried over, would be 17.* *Which again would be one down on the bottom line.* *Two over there...3, 4, 5, 6.*	Analyse concept phase
Equals 611C. *Mmmm.*	Test concept phase
I'll try to work this out again.	Return loop
A would be ten...plus the two would be C. *E is 14 and 3 is equal to 17.* *Em, not really sure what I'm doing at the moment.* *Obviously what I'd done before was incorrect.* *Just trying to figure out another way around it.* *F was 15.* *If I kept that the way it was.* *Zero and you were carrying over the two.* *No, you were carrying over the one.* *·What did we do before..A was ten.* *So we're going back to the previous exercise again.* *16.* *Zero..but you had the one carried over.* *Which would that would be one..with the one carried over.* *Right, we've got F, which is 15.*	Analyse concept phase

And you're adding it to zero...plus the one...plus the one you've carried over, so that would be 15, 16, should be one, zero..be 3, 4, 5.

501C.

There we go.

OK.

On to the next chapter.

Analyse concept phase
Test concept phase

Student 7 (time spent on screen – 257sec.)

Student 7 also chose to employ paper in support of his orientation and initial analysis phases for the on-screen problem. Observational evidence indicated that he had experienced difficulty in conceptualising the problem from the information that was available, he therefore briefly reviewed a number of the options inside the toolbox facility before returning to his paper notes. These consisted of no more that a setting out of the question. Interestingly, this happened within five seconds of his verbalising, *'The tools in the box may be helpful, but try not to use them.'*, which may indicate a degree of de-motivation at this stage.

With regard to the predicted model, both his verbal protocol and observational data indicated that his approach was to initiate a number of return loops at the orientation and analysis phases prior to his entering the test phase, where he input an incorrect answer on-screen. Subsequently he initiated another return loop and opened the hexadecimal calculator inside the toolbox. His use of the hexadecimal calculator could be characterised as a 'chunking' approach, where he calculated each combination in turn using the calculator to make up the answer. Although his theoretical processing appeared to be correct, his chunking approach meant that he failed to include a carry during the calculation, leading to another incorrect (4F1C in lieu of 501C) answer being input on-screen. He made no attempt to enter a reflection phase, or to engage another return loop prior to moving on to the next screen

"Now try the following hexadecimal addition.

Remember to give 4 digits.

The tools in the box may be helpful, but try not

Read text phase

to use them.	Read text phase
Right, so it will be 1F3A, which is 30E2, which is 10 and 2's 12. *(Sighs)...binary-hex conversion.* *(Sighs)Right, em, E is 10, 11, 12, is 15.* *Right F and 0 is tsts...em, F is 16.* *16...and 3 and (mumbles) 1 and 3 is 4.* *Soooo...2 carry 1, which is 16 carry 1, which is 17, carry 1, which is 5.* *Is 6, 2.*	Analyse concept phase
Equals 562. *(Sighs)...ttstststs.*	Test concept phase
Hmhm...so A plus 2 equals 12, or C.	Return loop
Oh right (sighs), that changes that bit. *A, 2, which is C.* *And ttttttt...and 3 plus E...equals 11.* *F plus 0...equals F, obviously.* *And 3 plus 1, which is 4.*	Analyse concept phase
4FIC. Nope (sighs).	Test concept phase

6.10.2. Validation of Completeness of Models

In order to determine whether they had complied with the predicted procedural models, each student's verbal protocol was coded according to the predicted phases of the procedural models for each screen within the module. The coding was carried out using the NVivo software package and was done in conjunction with the analysis of student activity through screen capture. Observational notes and screen capture data were used alongside the verbal protocols for the purposes of verification during the coding process. A full analysis of each student's processing behaviour can be viewed in Appendix R.

Analysis of the data obtained from these measures indicated a general compliance with the procedural models outlined, with the exception of the reflection phase which was often not present. The models themselves proved to be fairly robust, with any additional coding fragments typically emanating from interface problems encountered by the students as they worked through the module. The following discussion will consider the completeness of each model in turn.

6.10.2.1. Completeness of Model 1

The first procedural model was relatively simplistic due to the content of the screens, which was purely textual and static. This may explain the generally truncated approach to the predicted model by most of the students, with little evidence of an orientation phase and only two instances of reflective behaviour from student 5. There were no instances of the initiation of return loops by any student during any of these screens.

It could be speculated that the content of the screens may have been a contributing factor to the lack of completeness of the procedural model. Because the screens contained only instructions on how to use the package and introductory text on the objectives of the module, the students appeared to ascribe little value to them. In the case of the package instructions, this led to some facilities being missed by students and occasional problems with the interface.

6.10.2.2. Completeness of Model 2

The analysis of student behaviour during model 2 screens showed a variation in their compliance with the procedural model. Out of the fourteen model 2 screens within the module, students 2, 3, 4 and 7 were seen to generally comply with the model in its entirety, while students 1, 5 and 6 only partially complied. In each of the latter cases the general lack of any observable reflective behaviour was responsible for the incomplete model. It was particularly noted that neither of students 1 or 5 entered a reflection phase during any of these screens.

Observational evidence suggested that much of the students' reflective behaviour took the form of post-animation analysis of the concept that had been demonstrated. As discussed earlier, this appeared to be largely due to the students' inability to process textual and pictorial media at the same time as cognitively processing the conceptual content of the animation.

In the case of student 6, it was noted that although she generally failed to comply with the predicted model through her omission of a reflection phase, she did initiate a number of return loops, which typically took the form of additional reviews of the animated media. These additional reviews were used as a means of taking paper notes and carrying out additional conceptual analysis. This may have negated the need for a reflection phase in her case. In this regard, her processing behaviour differed from students 1 and 5, as neither of these students entered a reflection phase or initiated return loops in support of the analysis phase.

The importance of the reflection phase and/or return loops in providing additional time for conceptual analysis was evident when considering each student's approach to model 3 and 4 screens, with students 1 and 5 failing to engage any observable testing phase during nine and twelve out of fourteen of the applicable screens respectively.

Again, there was evidence of fragmentary additional phases within some student's verbal protocols, although these were generally attributable to problems with the user interface, in the form of missing or misinterpreting of interactive elements. Students 2 and 4 were both observed to have entered a separate analysis phase which hadn't been anticipated prior to the process animation phase. They used these additional analysis phases to predict the outcome of the animation before it had been started.

6.10.2.3. Completeness of Model 3

The analysis of procedural phases during model 3 screens provided clear evidence of a goal-orientated approach by some students in their use of the package. Because these screens required the student to answer one or more closed questions, of the drag and drop or multiple choice type, it was anticipated that they would require both an analysis and a testing phase to complete the screen, with a period or periods of reflection during and after the questions, as required.

The analysis showed only a partial completion of the predicted model for all but student 3, with the reflection phase missing for the other six students. The omission of the reflection phase could in part be attributed to a goal-orientated approach, which was discussed earlier in this chapter. It would also be reasonable to speculate that the nature of the questions did not promote reflective behaviour because of the question types.

Students 1 and 5 again exhibited truncated versions of the predicted model with limited evidence of effective analysis or testing phases present. This was further supported by their observed use of trial and error in reaching a solution to on-screen questions on five and seven out of seven occasions respectively. Any fragmentary phases that were observed during model 3 screens were once again typically derived from problems encountered with the interface.

6.10.2.4. Completeness of Model 4

Model 4 screens differed from model 3 screens in the nature of problem solving required by the questions. Due to their open nature, it was anticipated that a more complex and rigorous procedural model would be required to complete these screens. In particular, it was anticipated that a greater degree of analysis, which would require either mental or paper based calculation would be evident. It was also anticipated that the screens would promote a greater degree of reflective behaviour among the students and that there would be more observable use of return loops between the analysis and testing phases.

This was indeed seen to be the case as evidenced earlier through the analysis of student verbal protocols, although individual student approaches varied widely. Students 2, 3 and 6 were observed to have generally complied with the predicted model, including evidence of multiple reflection phases and return loops. It was noted that student 2 on a number of occasions used the reflection phase as a means of post-testing conceptual analysis due to his tendency to use the facilities within the on-screen toolbox in order to achieve a correct answer. In this sense, the order in which he followed the model differed somewhat from the predicted model.

While students 4 and 7 complied with the predicted model on some screens, their approach was inconsistent. In the case of student 4, compliance was observed to drop off as he progressed through the package. There was enough evidence of his frustration during his time on the module to suggest that his de-motivation would have been largely responsible for his limited conceptual interaction with the package towards the end. Students 1 and 7 tended to follow a truncated version of the predicted model, with little evidence of an orientation phase from student 7, and little evidence of a reflection phase from both students. Student 5 took a very surface approach to the screens with little or no evidence of moving beyond the orientation phase during all of them.

Problems with the user-interface caused the learning process to break down for some students during model 4 screens. This was particularly evident for students 3 and 4 who experienced considerable problems with inputting answers. This led to instances of reflection and the initiation of return loops that would not have been anticipated. More importantly, it negated the learning attained during the analysis phase culminating in instances of 'unlearning' of the concept. Student 1's failure to validate his answers during these screens provided little opportunity for him to enter an effective reflection phase, as he had no datum answer to reflect upon.

6.10.3. Validation of Level of Detail of Models

The final of the three validation considerations during the analysis of students' verbal protocols examined the level of detail of the procedural models used. The analysis of the verbal protocols did not identify any procedural phases that remained unobserved throughout students' use of the EDEC package. While individual students' verbal protocols did highlight the absence of a predicted reflection phase, the general pattern of behaviour observed for the sample as a whole demonstrated enough evidence of reflective behaviour to justify its inclusion in the general procedural models.

6.11. How the Findings Relate to Students' Cognitive Style

When the students' approach to EDEC was considered alongside their cognitive style over the two dimensions tested by Riding's Cognitive Styles Analysis test (CSA), no clear patterns emerged that could be related to characteristics of the students' processing behaviour. Table 137 provides a breakdown of each student's cognitive style for each of the wholist/analytic and verbaliser/imager dimensions.

Breakdown of Students' Cognitive Style from Cognitive Styles Analysis Test (CSA)		
Student No.	**Wholist/Analytic Style**	**Verbaliser/Imager Style**
Student 1	Analytic	Imager
Student 2	Analytic	Imager
Student 3	Analytic	Bimodal
Student 4	Wholist	Verbaliser
Student 5	Wholist	Verbaliser
Student 6	Wholist	Verbaliser
Student 7	Analytic	Bimodal

Table 137

One interesting finding arose when students' differential performance over the pre-post test quizzes was compared with each style dimension. Tables 138 and 139 show that those students who profiled as analytic and imager tended to perform better than those who profiled as wholist and verbaliser. Student 6 who had the highest differential score can however be seen to contradict any trend that was observed for each dimension. It was noted that student 6 spent considerably more time on the package than the other students (140% of mean time) and that this may have contributed to her high score irrespective of cognitive style.

Comparison of Wholist/Analytic Style and Pre/Post-Test Quiz Differential Score

Count

		Wholist/Analytic Style	
		Wholist	Analytic
Pre/Post-Test Quiz Differential Score	2	1	
	3	1	
	4		2
	5		2
	6	1	
Total		3	4

Table 138

Comparison of Verbaliser/Imager Style and Pre/Post-Test Quiz Differential Score

Count

		Verbaliser/Imager Style		
		Verbaliser	Bimodal	Imager
Pre/Post-Test Quiz Differential Score	2	1		
	3	1		
	4		1	1
	5		1	1
	6	1		
Total		3	2	2

Table 139

When cognitive style was compared with students' perceptions of the package and time spent on the different screen types, no trend was observed. In general. there was little evidence of cognitive style having a decisive bearing on the students' ability to use the package or their performance based on pre/post testing. An analysis of cognitive style and the students' compliance with the predicted procedural models was carried out in order to ascertain whether cognitive predisposition in either of the two style dimensions had any bearing on students' approach to processing the different screen types (see Tables 140 to 143). While the results demonstrated no clear pattern, they did indicate that analytic students were more likely to complete the predicted processing phases for model 2 screens than their wholist counterparts. This was interesting as model 2 screens were those which required the processing of both textual and animated media and implies that the wholist students may have had more difficulty with these screens than those who profiled as analytic.

Comparison of Wholist/Analytic Style and Completeness of Model 1 Screens

Count

		Completeness of Model 1 Screens	
		incomplete	complete
Wholist/Analytic Style	Wholist	3	
	Analytic	3	1

Table 140

Comparison of Wholist/Analytic Style and Completeness of Model 2 Screens

Count

		Completeness of Model 2 Screens	
		incomplete	complete
Wholist/Analytic Style	Wholist	2	1
	Analytic	1	3

Table 141

Comparison of Wholist/Analytic Style and Completeness of Model 3 Screens

Count

		Completeness of Model 3 Screens	
		incomplete	complete
Wholist/Analytic Style	Wholist	3	
	Analytic	3	1

Table 142

Comparison of Wholist/Analytic Style and Completeness of Model 4 Screens

Count

		Completeness of Model 4 Screens	
		incomplete	complete
Wholist/Analytic Style	Wholist	2	1
	Analytic	2	2

Table 143

When each of the *'analysis'*, *'testing'* and *'reflection'* phases were considered alongside wholist/analytic style separately (see Tables 144 to 146) the results indicated that analytic students were more likely to engage *'analysis'* and *'testing'* phases than wholists. They were also more likely to engage multiple *'reflection'* phases during and at the end of processing than wholists.

Comparison of Wholist/Analytic Style and Instances of Student Analysis of Concept

Count

		Number of Analysis phases				
		1	9	10	13	14
Wholist/Analytic Style	Wholist	1		1	1	
	Analytic		1			3

Table 144

Comparison of Wholist/Analytic Style and Instances of Student Testing of Concept

Count

		Number of Test phases					
		1	9	11	13	14	26
Wholist/Analytic Style	Wholist	1		1	1		
	Analytic		1			2	1

Table 145

Comparison of Wholist/Analytic Style and Instances of Student Reflection

Count

		Number of instances of reflection phase					
		3	11	12	13	28	46
Wholist/Analytic Style	Wholist	1		1	1		
	Analytic	1	1			1	1

Table 146

The same comparative analyses for the verbaliser/imager style dimension indicated that verbaliser students were perhaps less likely to complete the predicted processing phases for model 2 screens than bimodal or imager students (Table 147), although the small sample size made it difficult to make any definitive claim in this regard. There was no indication of any pattern for the other three screen types (Tables 148 to 150).

Comparison of Verbaliser/Imager Style and Completeness of Model 1 Screens

Count

		Completeness of Model 1 Screens	
		incomplete	complete
Verbaliser/Imager Style	Verbaliser	3	
	Bimodal	2	
	Imager	1	1

Table 147

Comparison of Verbaliser/Imager Style and Completeness of Model 2 Screens

Count

		Completeness of Model 2 Screens	
		incomplete	complete
Verbaliser/Imager Style	Verbaliser	2	1
	Bimodal		2
	Imager	1	1

Table 148

Comparison of Verbaliser/Imager Style and Completeness of Model 3 Screens

Count

		Completeness of Model 3 Screens	
		incomplete	complete
Verbaliser/Imager Style	Verbaliser	3	
	Bimodal	1	1
	Imager	2	

Table 149

Comparison of Verbaliser/Imager Style and Completeness of Model 4 Screens

Count

		Completeness of Model 4 Screens	
		incomplete	complete
Verbaliser/Imager Style	Verbaliser	2	1
	Bimodal	1	1
	Imager	1	1

Table 150

When the '*analysis*', '*testing*' and '*reflection*' phases were compared with verbaliser/imager style, no conclusive pattern was observed, although there was a greater frequency of '*analysis*' and '*testing*' phases among bimodal and imager students than verbalisers. This would perhaps have been expected due to the highly visual nature of the package (Tables 151 & 152). Verbaliser students were also less likely to engage multiple reflection phases than bimodal and imager students (Table 153).

Comparison of Verbaliser/Imager Style and Instances of Analysis of Concept

Count

		Number of Analysis phases				
		1	9	10	13	14
Verbaliser/Imager Style	Verbaliser	1		1	1	
	Bimodal					2
	Imager		1			1

Table 151

Comparison of Verbaliser/Imager Style and Instances of Testing of Concept

Count

		Number of Test phases					
		1	9	11	13	14	26
Verbaliser/Imager Style	Verbaliser	1		1	1		
	Bimodal					1	1
	Imager		1			1	

Table 152

Comparison of Verbaliser/Imager Style and Instances of Student Reflection

Count

		Number of instances of reflection phase					
		3	11	12	13	28	46
Verbaliser/Imager Style	Verbaliser	1		1	1		
	Bimodal		1				1
	Imager	1				1	

Table 153

With regard to the students' perceptions of the EDEC package, no observable relationship between perception and either cognitive style dimension was established relating to the presentation of media or overall perception.

6.12. How the Findings Relate to Students' Approach to Learning (R-SPQ-2F Results)

When considering students' approach to learning, be it deep or surface, the analysis of data gathered through qualitative methods employed during the case study cast doubt on the reliability of the findings from the Revised Study Process Questionnaire (Table 154). It has to be said that the results of student profiling through the questionnaire mapped poorly to the analysis of students' verbal protocols and observational data gathered during their use of the package. The lack of a representative distribution over each of the test scales (approach, strategy and motivation) was puzzling as I had worked with the students selected for three years previously and had expected to see a reasonable distribution before the questionnaire was administered.

Breakdown of Results from Revised Study Process Questionnaire (R-SPQ-2F)			
Student No.	**Deep/Surface approach**	**Deep/Surface motivation**	**Deep/Surface strategies**
Student 1	Deep approach	Deep motivation	Deep strategy
Student 2	Deep approach	Deep motivation	Surface strategy
Student 3	Deep approach	Deep motivation	Deep strategy
Student 4	Deep approach	Deep motivation	Deep strategy
Student 5	Deep approach	Deep motivation	Deep strategy
Student 6	Deep approach	Deep motivation	Deep strategy
Student 7	Deep approach	Deep motivation	Equal

Table 154

Since the data provided by the R-SPQ-2F identified all students as taking a generally deep approach to their learning, there was little scope for comparison across variables in this instance. It could be speculated that while the students did not intentionally fabricate their responses to the questionnaire, their perception of themselves as learners was different from that which was observed. Dweck's (2000, p.79) work on self-theories and misperception of self may explain this observation to a degree, as there may have been a tendency for the students to wish to project themselves as deep learners as a means of matching my expectations of them. There was certainly evidence of a surface approach by some students in their use of the package, as evidenced through observation and their verbal protocols. Conjecture as to whether the lack of vested interest in their use of EDEC may have been responsible for the approach adopted is to an extent countered by the students' discussion of their use of the CALMAT mathematics software during their studies.

6.13. Time Spent on Screens

An analysis of the time spent on each screen type was carried out with reference to the procedural models in order to determine whether time was a factor in students' use of the package as well as to establish patterns of behaviour for each individual student.

Table 155 shows the mean time spent on screen which conformed to the different procedural models. It can be seen from the table that students 1 and 5 spent more time on model 1 screens (text only) than the others, but considerably less time on model 2 screens (text and animation) and model 4 screens (calculation and data input). There was no observable difference in the time that they spent on model 3 screens (interaction) compared with the others. It is worth speculating that model 2 and model 4 screen would require a more rigorous degree of analysis and reflection due to the requirements of processing animated media and prolonged analysis and calculation phase required to solve open problems, when compared with model 3 screens, which could be completed through trial and error. This would imply a surface approach taken by the two students when compared with the others, and is further supported by their number of reflection phases initiated compared with the others (Table 156).

Mean Times Spent on Screen For Different Procedural Models in Seconds				
	Model 1 Screens	Model 2 Screens	Model 3 Screens	Model 4 Screens
Student 1	47	59	72	56
Student 2	16	87	78	277
Student 3	27	133	108	194
Student 4	29	92	88	184
Student 5	53	67	106	66
Student 6	9	130	73	328
Student 7	27	136	79	131

Table 155

Frequency of Coded Instances of Reflection Phase	
	Number of Instances
Student 1	3
Student 2	28
Student 3	46
Student 4	12
Student 5	3
Student 6	13
Student 7	11

Table 156

There was no evidence that the time the students spent on screen dropped off as they progressed through the package. When each screen type was analysed with regard to time, it was clear that the only discernable reduction in time spent on-screen came in the case of student 5 during model 3 and model 4 screens.

When time spent on the module was compared with other variables, such as performance and perceptions of the package, there was no conclusive indication of any relationship between the variables. One interesting finding came from the comparison of time spent on screens that complied with particular models. When the time that students' spent on model 2 screens was compared with the degree to which they valued the use of borrowed notes from other students, a strong relationship was found between the two variables as shown in Table 157. This finding may support the view that the students who spent less time on the module were more goal-orientated as has been discussed earlier. A distinction however needs to be drawn between the students' goal-orientated approach to the completion of the module and their motivation as a learner more generally. This was particularly the case for student 2, who spent less time on model 1, 2 and 3 screens than most other students, but spent the second longest amount of time on the more complex model 4 screens that required a more rigorous analysis phase.

Comparison of Mean Time Spent on Model 2 Screens and Usefulness of Borrowed Notes

Count

		Borrowed notes		
		Useless	Not very useful	Useful
Mean time spent on model 2 screens in seconds	59			1
	67			1
	87			1
	92		1	
	130		1	
	133	1		
	136		1	

Table 157

A similar relationship between time spent on model 4 screens and the usefulness of discussion with other students in support of their learning was observed as shown in Table 158.

Comparison of Mean Time Spent on Model 4 Screens and Usefulness of Discussion with Students

Count

		Discussion with students		
		Useful	Vital	Total
Mean time spent on model 4 screens	56		1	1
	66		1	1
	131		1	1
	184	1		1
	194	1		1
	277	1		1
	328	1		1
Total		4	3	7

Table 158

6.14. Discussion

While the first three case studies provided an opportunity to test a number of hypotheses statistically, the intention of the final case study was consider students use of the EDEC package in more depth and with a smaller sample. The data gathering methods were important in providing an insight into how the students cognitively processed information from the package and interacted with the learning concepts covered by the module. A number of issues became apparent during the case study that related to the design of the package and the students approach to using it.

The development of procedural models allowed actual student behaviour to be coded against predicted behaviour in terms of the processing phases outlined. The incomplete model for text only screens gave an initial insight into the students' goal-orientated approach to their use of the package. Observation of them during these screens, which both came at the start of the module, indicated an unwillingness to spend time on instructional content that was not related to the concepts covered by number systems. There was further evidence of skimming over instructional text in general from some students during their use of the package, which led to their missing interactive elements that were textual in nature. Perhaps the best example of this came during screen number 1.2.5, which was an animated demonstration screen conforming to model 3 (Figure 33).

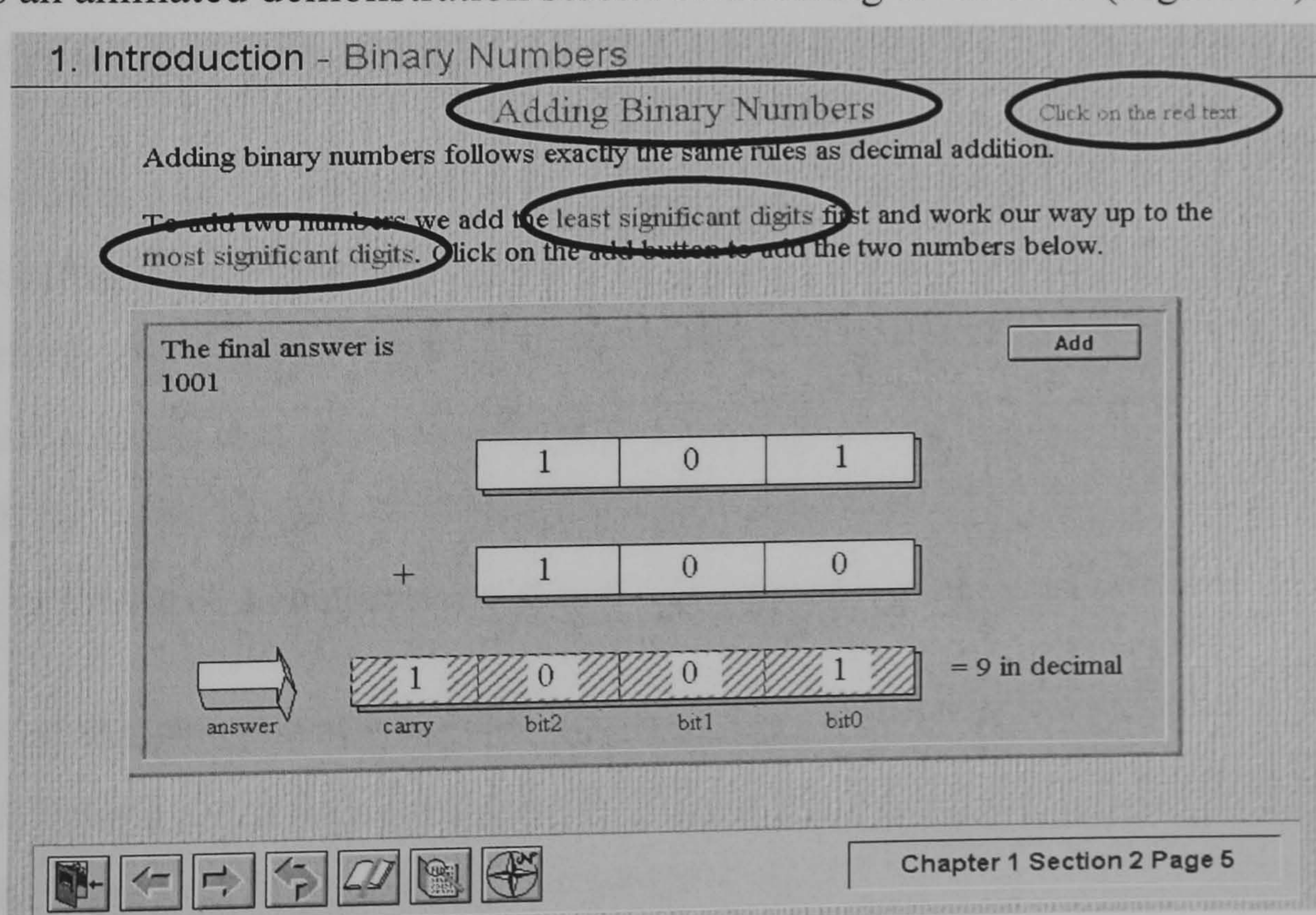


Figure 33

The screen demonstrates the problem with processing multiple items of text, and in particular, items of information that do not flow within the narrative thus requiring separate processing. It asks users to *'click on the red text'*, which resulted in more than one student clicking on the instruction itself because it was in red text (all on-screen items of red text are circled). More interesting was the effect of the positioning of the instruction, which led to only one student actually activating the areas of red text during their time on the screen. The fact that this instruction only appeared in two of the seven verbal protocols, even though five of the students verbalised the main introductory text would suggest that the students either chose to ignore the instruction, to get on to the animation, or were unable to process the text due to its on-screen position and their processing of the main text. Only one student actually initiated the interactive elements during their time on the screen.

Although the students had no vested interest in using the package during this case study (because it was not a formally assessed part of their course), their approach to it was consistent with that observed during the other case studies, and their perceptions of the package mirrored most closely those of the students in case study three, with a wide distribution of results and a higher degree of negative feedback. When the findings on perceptions are considered against those from the other case studies, they indicate a relationship between year of study and perception of EDEC. This will be discussed further in the next chapter.

Observation of the students during their use of the package highlighted a number of user-interface issues that had a role to play in determining the quality of the learning experience. These ranged from the use of blue text for emphasis on some screens that were misinterpreted as hyperlinks, to more serious problems with the input of data. Without doubt the most problematic of these proved to be the inputting of answers to open questions on model four screens.

Out of the seven students who made up the sample, five encountered problems with inputting answers during model 4 screens. In the case of students 2, 3, 4 and 7, their method of processing the problem during the analysis phase appeared to be the strongest contributing factor to their problems with the interface. The on-screen input window was set up to take a complete answer once it had been worked out, although it was observed that these students took a 'chunking' approach to solving the problem, one digit at a time. This led to their inputting data in chunks, with resultant problems with the order and significance of digits within the input window. This phenomenon manifested itself most profoundly on two occasions with students three and four as discussed earlier in this chapter.

In the case of student 1, the lack of clear instructions on how to input answers led to a complete failure on his part to validate any of his answers to model four questions, giving him no opportunity to confirm (through feedback) whether his conceptualising of the theory was correct or not. It was interesting to note that although this was the case, he seemed completely unconcerned with the lack of feedback received and more concerned with completing the task so that he could move on to the next screen.

It was clear from the verbal protocols and observational evidence that the problems experienced by some students with the user interface led to their becoming frustrated and de-motivated as they moved through the module, with a resultant drop off in processing. While the navigation system allowed users to move through the package in a manner which suited them, all of the students were observed to have adopted a completely linear approach to their navigation through the module.

The students' use of pen and paper in support of their learning provided an interesting insight into their approach to the package. Although most of them turned to paper at some point during the module, only student 6 was observed to have taken notes in support of the 'analyse concept' phase (i.e. notes derived from the concept being demonstrated). All of the others used paper solely for calculation purposes. The result of this was that only student six had any sort of record of the concepts covered by the module. Her taking of notes, which typically took place during animated demonstration screens, did however lead to processing problems, with evidence of her note-taking leading to fragmented analysis phases. This typically manifested itself through her initiation of multiple return loops during these screens. The lack of structure to the students' note-taking while using the package led to an over-reliance on short-term recall from previous screens when tackling problems which consequently led to incorrect recall at times, thus short-circuiting the learning process.

It was noted that the students tended to be very goal-orientated in their approach to the package. By that I would suggest that they primarily viewed the package as no more than an assessment interface, as against a learning resource. The lack of an observable reflection phase during the processing of model 3 screens, with the exception of student 3, highlighted the students' propensity to move on to the next screen immediately after answering any questions without any further reflection on the concept or concepts demonstrated. It was even more obvious on occasions where they chose an incorrect answer during multiple choice or drag and drop questions. While the predicted model would have anticipated the initiation of a return loop, resulting in further analysis and testing phases. the students' verbal protocols and observation indicated their resorting to trial and error to achieve a subsequent correct answer before moving on without further reflection.

While it could be said that the repeating structure of the package was intended to promote ease of progression and minimise any additional processing burden imposed by the interface. it also had a role to play in students becoming de-motivated and skimming information or missing it out altogether. if they had experienced earlier problems with particular screen types. This was particularly apparent during model 4 screens, where the students often attempted the question without any reading of the introductory text, potentially missing key instructions on how to tackle the question.

One interesting phenomenon encountered during the case study, was the approach taken by most students' during the analysis phase of model 4 questions, where they separated their knowledge of the binary number system from that of the decimal system of which they were more familiar. In most cases they attempted calculations using the methods outlined on-screen and rarely employed conversion from binary or hexadecimal to decimal as one would have perhaps expected. Some of the strongest evidence of this came from the analysis of the students' verbal protocols for model 4 screen 1.3.5 (see section 6.10.1.4.2 of this chapter). Although some students inappropriately referred to binary numbers in decimal, for example 10 (2 in binary) as ten, they appeared unwilling or unable to shift conceptually from one system to another during calculation.

A reconsideration of Atkinson and Shiffrin's (1968) model of information processing (Figure 12, p.24) highlighted the need for more rigorous consideration of the impact of different visual media on the processing of information to short-term memory through the visual register. This was particularly the case with the processing of animated media, which required both sequential and parallel processing of information. It was clear during the analysis of model 2 screens that most students had experienced difficulty with recall from short-term memory with regard to information which had been processed from animated media. This resulted in a need for multiple return loops in some instances, which led to a degree of frustration and de-motivation among some students. This was exacerbated by their lack of note-taking.

While there was some evidence of the students attempting to process animated media in manageable chunks, the lack of control of animations made this difficult. There were a number of occasions where a student was observed taking paper notes during an animation or changing screen during an animation. Students 6 and 7 in particular were observed to have initiated multiple return loops during model 2 screens to facilitate a chunking approach to their processing of information. In the case of student 6, multiple return loops were employed to facilitate the taking of paper notes that she then referred to during subsequent screens. She was the only student to employ this approach.

The limited use of return loops by some students, for the review and reinforcement of previous learning, placed an additional cognitive burden on short-term memory that resulted in limited conceptual analysis during some model 4 screens. Interestingly, the students generally appeared to be reluctant to navigate back to previous screens, instead relying on short-term recall for conceptual knowledge and understanding, which at times led to fragmented analysis phases. There was strong evidence to suggest that they viewed the package more in terms of assessment of knowledge than learning per se. This tended to result in a very goal-orientated approach to their navigation through the package. It was noted in particular that those students who were observed to have taken a trial and error approach to questions during model 3 screens were more concerned with achieving a correct answer than gaining an understanding of the concepts under test. It may be that these students were acting in a *'performance goal'* manner as identified by Dweck (see section 2.7), where a fear of failure influenced their processing behaviour. Evidence for this was present in some students' use of trial and error for multiple choice and drag and drop questions. This was most pronounced in the case of student 5, who often failed to progress beyond the *'orientate'* phase during model 4 screens, which included open calculation questions. Of the two question screen types, there was a clear distinction between how the students employed the analysis and testing phases during these screens. The analysis of data indicated that the *'analysis'* and *'test concept'* phases of model 3 screens tended to be compressed into a single phase, which was characterised by the use of trial and error. Even when a trial and error approach was not employed, the type of questions did not promote any substantial reflective behaviour, with the exception of student 3. It was notable that when the students received feedback from the system to go back to a previous screen on the submission of an incorrect answer, on no occasion was this acted upon. This once again highlighted the goal-orientated approach taken by the students in their use of the package.

Note:

While all student verbal protocols and interviews were fully transcribed prior to analysis, they have not been included as appendices in the thesis, in order to ensure that its size did not become unmanageable. These, along with the observation logs created for each student will be permanently retained and can be made available to the reader upon request by contacting the author.

Chapter Seven

Overview of Findings from the Four Case Studies

7. Introduction

The purpose of this chapter is to discuss the general findings of the research and to allow the meta-analysis of data collected over the four cases studies.

7.1. Design Issues

The experimental design phase of the project highlighted a number of issues that would inform and sometimes hinder the progress of the research. The mixed-methods approach employed necessitated the careful consideration of selection and balance of methods and instruments that would be utilised during the case studies. As discussed in chapter two, the use of a mixed-methods approach can have considerable implications for the outcomes of any evaluation, due the sometimes complex interactions which take place between methods and instruments (Lawrenz and Huffman, 2002). To this end, it was important that the data gathering instruments were complementary in nature for triangulation purposes and manageable in terms of their use in real learning situations.

The use of a generally quantitative methodological approach to data gathering during the first three case studies provided a platform for the more qualitative methodologies employed during the final case study. The decision to use profiling instruments such as the Cognitive Styles Analysis (CSA) test and the Revised Study Process Questionnaire (R-SPQ-2F) was taken on the basis of their ability to provide raw data for later analysis through any proprietary statistics package and also for their ease of administration. In the case of the Revised Study Process Questionnaire, it was decided that while this diluted version was less rigorous than Biggs' (1978, 1985) original Study Process Questionnaire (SPQ), it provided the most manageable option in terms of ease of administration.

One of the main concerns with the experimental design used during the first three case studies was the ease with which instruments could be administered. This was due to the situated nature of the research, which was carried out within actual classes and covered assessed course elements. The collection of data over the short periods of time in which I had access to the samples, required sensitivity to the needs of the students while allowing the collection of sufficient data to meet the needs of the research. I was particularly concerned not to de-motivate the students through over-exposure to a number of different methods and instruments in such a short space of time, although there proved to be no evidence of this being the case.

Some problems with the experimental design were encountered early on, where it became apparent that a generic experimental design could not be applied across each of the first three case studies. The negotiation with teaching staff at the start of each case study became vital in defining the appropriateness of individual instruments to the learning environment. To this end, it was decided at an early stage that a composite questionnaire would be used which would incorporate the Learning Resource Questionnaire, the Students Perceptions Questionnaire and the R-SPQ-2F in lieu of separate instruments. While this meant that the questionnaire took around fifteen minutes to complete, it was considered to be preferable to the administration of several discrete instruments over a number of sessions. It also freed up time for the administration of other complementary instruments.

The use of quantitative measures also posed a potential problem, since the sample sizes available at each institution were defined by the actual class size. This led to relatively small sample sizes at two of the three institutions under evaluation, with implications for the validity of any statistical analysis, although the combined sample used during the analysis covered by this chapter was sufficient to alleviate any problems with validity.

7.2. The Case Studies

While the approach taken during the first three case studies provided an opportunity to evaluate students' use of EDEC in actual learning environments, there was a need to gain a deeper insight into their behaviour as they used the package. This was achieved through the final case study, which followed a smaller controlled sample of students as they used EDEC. The methodologies employed in the fourth case study allowed a more detailed evaluation of the students' information processing behaviour, thus providing a combined dataset over the four case studies at both macro and micro levels.

7.3. Meta-analysis of Findings

The following sections will discuss selected analyses of data from the combined dataset gathered from the four case studies. Where possible, data from all four case studies were used in the analysis, although in some instances, where data was unavailable for a particular sample, the available accumulated sample was utilised.

7.4. Usefulness of Resources

The aggregate results from the Learning Resource Questionnaire highlighted the importance of social, 'face to face' interaction to students in their learning, as was evident from each of the individual case studies. As Table 159 shows, lectures and discussion figured prominently in the students' resource preferences.

Usefulness of resource (overall sample) in percent Number of responses for each category given in brackets (e.g. N=81)					
	Useless	**Not very useful**	**Useful**	**Vital**	**Not sure**
Lectures (N=81)	5	5	38	49	3
Textbook(s) (N=80)	11	15	46	23	5
EDEC computer package (N=81)	1	22	57	16	4
Own notes from lectures/labs (N=80)	1	3	46	50	0
Borrowed notes from someone else (N=78)	22	28	41	3	6
Discussions with tutor/lecturer (N=78)	1	4	56	36	3
Discussions with other students (N=81)	3	8	60	29	0
Other resources (N=48)	10	15	36	27	13

Table 159

The basis for their preference for 'face to face' interaction may lie in the learner's need for human interaction as validation of actual learning through reflection, testing and repetition of what has been learned as a series of conversations as discussed in the works of Laurillard, (1993) and Pask (1975). In general the results demonstrated a diversity of resource preference among the students and highlighted the need for educators to give careful consideration to the use of ICT resources within the wider learning environment as highlighted by a number of authors (Richardson and Turner, 2000, Laurillard, 1993).

When the results were considered with regard to the students' year of study (see Table 160) a degree of correlation was observed in their responses to the usefulness of lectures, own notes and the EDEC package. Although these results may be due to a degree of conditioning of the students towards particular resources, they may also highlight the differing needs and approaches of students to their learning as they become mature learners (Perry, 1970, 1981).

Comparison of Usefuleness of Resources and Year of Study

			Year of study
Spearman's rho	Lectures	Correlation Coefficient	.343**
		Sig. (2-tailed)	.002
		N	81
	Textbook(s)	Correlation Coefficient	.273*
		Sig. (2-tailed)	.014
		N	80
	EDEC computer package	Correlation Coefficient	-.226*
		Sig. (2-tailed)	.043
		N	81
	Own notes from lectures/labs	Correlation Coefficient	-.006
		Sig. (2-tailed)	.961
		N	80
	Borrowed notes from someone else	Correlation Coefficient	-.138
		Sig. (2-tailed)	.229
		N	78
	Discussion with tutor/lecturer	Correlation Coefficient	-.136
		Sig. (2-tailed)	.235
		N	78
	Discussion with other students	Correlation Coefficient	-.148
		Sig. (2-tailed)	.186
		N	81
	Other resources	Correlation Coefficient	.031
		Sig. (2-tailed)	.835
		N	48

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 160

7.5. Student Performance in Pre/Post-Test Quizzes

While there was a demonstrable increase in performance during the pre/post-test quizzes administered during case studies 2 and 4 (see Tables 161 & 162), no statistical relationship between performance and students' cognitive style or approach to learning (deep/surface) was evident. Similarly, no relationship was established between student confidence and cognitive style during case study 3, suggesting that performance and confidence was independent of cognitive style. It would also imply that the method of delivery of media had little or no impact on performance based on cognitive style.

Pre/Post-Test Quiz Perfomance - Case Study 2

		Number of correct answers (Pre-Test 1)	Number of correct answers (Post-Test 1)	Number of correct answers (Pre-Test 2)	Number of correct answers (Post-Test 2)
N	Valid	49	49	34	34
Mean		7.35	9.55	5.94	8.74
Median		8.00	10.00	6.00	9.00

Table 161

Pre/Post-Test Quiz Perfomance - Case Study 4

		Number of correct answers (Pre-Test)	Number of correct answers (Post-Test)
N	Valid	7	7
Mean		2.71	6.86
Median		2.00	6.00

Table 162

A statistical analysis of pre/post-test quiz scores for the Number Systems EDEC module, which was used during case studies two and four was carried out, with the differential scores for the overall sample compared according to cognitive style (see Table 163). The results obtained using Pearson's test clearly indicated no significant relationship between differential score and either cognitive style dimension.

Comparison of Cognitive Style and the Students' Differential Score in Number Systems Quiz

		Test 1 Differential
Wholist/Analytic Ratio	Pearson Correlation	-.106
	Sig. (2-tailed)	.487
	N	45
Verbal/Imagery Ratio	Pearson Correlation	-.024
	Sig. (2-tailed)	.877
	N	45

Table 163

While the analysis of the second quiz carried out during case study two showed a stronger relationship between the verbaliser/imager style dimension and differential score (corr. coeff. = -0.384, p=0.053), the results for the Number Systems quiz carried out with the same sample indicated no significant relationship between the style dimension and performance (corr. coeff. = -0.046, p=0.787). These findings tend to contradict the indication of a relationship observed during the analysis of data from the fourth case study, which showed the possibility of a relationship over both style dimensions. On balance it has to be concluded that the case study four findings may have been spurious due to the small sample size. In general, it must be concluded from the analyses that student performance using the EDEC package was independent of cognitive style over both style dimensions.

7.6. Student Perceptions of the EDEC Package

The data from the perceptions questionnaire for each case study was collated to facilitate analysis across institutions and for different year groups. Table 164 shows students' perceptions of learning using computer packages. The results show a significant drop off in those students who agreed/strongly agreed that they liked to learn using computer packages according to year of study (see Table 165).

Students' Perceptions of Learning Using Computer Packages in Percent

	Institution 1 (1st year) Agree / strongly agree	Institution 2 (2nd year) Agree / strongly agree	Institution 3 (4th year) Agree / strongly agree	Institution 4 (3rd year) Agree / strongly agree	Total Sample Agree / strongly agree
I like to learn using computer packages.	77	66	14	29	59

Table 164

Comparison of the Students' Perceptions of Learning Using Computer Packages and Year of Study

			Year of study
Spearman's rho	I like to learn using computer packages.	Correlation Coefficient	-.362**
		Sig. (2-tailed)	.001
		N	81

**. Correlation is significant at the .01 level (2-tailed).

Table 165

The students' rather equivocal perception of the use of computer packages in support of their learning was not repeated when evaluating their perceptions of the Internet, as a learning resource. Table 166 shows that the vast majority of students at all four institutions indicated a positive perception of the Internet as a learning resource.

Students' Perceptions of the Internet as a Learning Resource in Percent					
	Institution 1 (1st year) Agree / strongly agree	**Institution 2 (2nd year) Agree / strongly agree**	**Institution 3 (4th year) Agree / strongly agree**	**Institution 4 (3rd year) Agree / strongly agree**	**Total Sample Agree / strongly agree**
The Internet is very useful to my learning.	78	71	86	86	80

Table 166

It is important to differentiate between the method of delivery of a particular learning resource, such as the EDEC package via the Internet and students' use of the Internet as a research and learning resource in a more generalised manner. The results would indicate that the students perceived the Internet as a valuable tool for their own self-directed learning over its value as a delivery platform. This conflicted with the perceptions of teaching staff and the EDEC developers, who typically cited the benefits of the Internet in providing a flexible delivery for the EDEC resource in isolation of the wider learning environment. Certainly, observational and interview evidence from case studies one to three showed minimal tutor interaction with students, and little structured use of the package alongside other resources.

When a comparison of students' overall perceptions of the EDEC package was carried out across the four institutions, it became apparent that their perceptions once again dropped off according to their year of study (Table 167). Again, this could be attributed to the more rigorous critical evaluation of resources by students, as they matured as learners. This point came across strongly during one of the focus groups in case study three, where a number of the students indicated that they had used resources other than EDEC to learn some of the topics required of them. It was clear from discussion that they had sourced and disseminated these resources themselves. The same students also indicated that they would have preferred to receive the EDEC material in paper format so that they could use the content in conjunction with other resources, instead of being locked in to EDEC alone. The degree of frustration observed from some students during case study four also highlighted the problems that may arise from the locking of students in to a particular resource. In this case it was observed to have led to a truncating of processing phases, resulting in a drop off in the learning process for some students.

Overall Student Perceptions of EDEC System in Percent					
	Institution 1 (1st year) Agree / strongly agree	**Institution 2 (2nd year) Agree / strongly agree**	**Institution 3 (4th year) Agree / strongly agree**	**Institution 4 (3rd year) Agree / strongly agree**	**Total Sample Agree / strongly agree**
Overall, I liked using the system.	77	71	7	29	52
I would use this system again in my studying.	69	60	14	43	46
I would recommend the system to other students.	87	66	14	57	53

Table 167

While there appeared to be a clear link between year of study and the students' perceptions of EDEC, it is important to recognise that there might have been other contributing factors in determining the results. These included the choice and level of subject matter within the modules and different approaches to the learning environment. The structure of the course in the third case study also differed from the first two in terms of the lecturer's expectations of the students and the volume of work that he expected them to complete during each EDEC session. While the expectation of the lecturer in case studies one and two was for students to have completed a single EDEC module during a single three hour lab session, this increased to an average of two per two hour session for the third sample. This necessitated additional independent work with the package for all of these students, while there was no evidence of this being the case for the students in case studies one and two.

When cognitive style was considered against other variables, for the combined sample from case studies 2 to 4, there was no observed relationship established between the students' overall perceptions of the package and cognitive style across either of the two style dimensions (see Table 168).

Comparison of Cognitive Style and Overall Perceptions of EDEC

			Overall, I liked using the system.	I would use this system again in my studying.	I would recommend the system to other students.
Spearman's rho	Wholist/Analyst Ratio	Correlation Coefficient	.020	.019	-.088
		Sig. (2-tailed)	.891	.899	.551
		N	48	48	48
	Verbal/Imagery Ratio	Correlation Coefficient	.015	-.003	-.034
		Sig. (2-tailed)	.921	.985	.818
		N	48	48	48

Table 168

While there was no statistical evidence of any difference in students' perceptions of the package overall, in relation to cognitive style, the analysis of their comments from the questionnaires provided a different picture. When the comments were categorised as positive or negative against the two style dimensions (organisational and sensory) it became evident that analytic students were typically more positive in their comments than those who profiled as wholist (Table 169).

Comparison of Students' Comments on EDEC and Wholist/Analytic Style

Count

		Comments from EDEC perceptions questionnaire	
		positive comment	negative comment
Wholist/Analyst Style	Wholist	0	7
	Intermediate	2	5
	Analytic	6	4
Total		8	16

Table 169

Similarly, when student comments were analysed against sensory cognitive style, the results demonstrated a more negative response in general from bimodal and imager students than those who profiled as verbaliser (Table 170). This was a little surprising, as it had been anticipated that the design of the package would have promoted a more positive response from imager students.

Comparison of Students' Comments on EDEC and Verbaliser/Imager Style

Count

		Comments from EDEC perceptions questionnaire	
		positive comment	negative comment
Verbaliser/Imager Style	Verbaliser	4	4
	Bimodal	2	5
	Imager	2	7
Total		8	16

Table 170

When approach to learning was considered for the entire sample from the four case studies, a clear relationship was observed between deep/surface approach to learning and students' perceptions of the EDEC package. In particular, there was clear evidence of those students who tended towards the deep end of the scale being more positively disposed towards the EDEC package than those who demonstrated a surface tendency (Table 171).

Comparison of R-SPQ-2F Results and the Students' Overall Perceptions of EDEC

			Overall, I liked using the system.	I would use this system again in my studying.	I would recommend the system to other students.
Spearman's rho	Deep approach	Correlation Coefficient	.311**	.111	.167
		Sig. (2-tailed)	.005	.325	.136
		N	81	81	81
	Surface approach	Correlation Coefficient	.098	-.061	-.127
		Sig. (2-tailed)	.385	.591	.257
		N	81	81	81
	Deep strategy	Correlation Coefficient	.250*	.131	.259*
		Sig. (2-tailed)	.032	.266	.026
		N	74	74	74
	Surface strategy	Correlation Coefficient	-.161	-.152	-.161
		Sig. (2-tailed)	.171	.195	.170
		N	74	74	74
	Deep motive	Correlation Coefficient	.231*	.045	.112
		Sig. (2-tailed)	.038	.693	.319
		N	81	81	81
	Surface motive	Correlation Coefficient	-.006	-.078	-.079
		Sig. (2-tailed)	.961	.508	.506
		N	74	74	74

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 171

With regard to the delivery of media, a significant relationship was observed between those students with a surface tendency over the three measures and their perceptions of the speed of animations (Table 172). While the correlation coefficients do not imply a particularly strong relationship, the findings were interesting nevertheless, as they alluded to processing problems among some students.

Comparison of R-SPQ-2F Results and the Students' Perception of the Speed of Animations

			I found the animated elements too fast.
Spearman's rho	Deep approach	Correlation Coefficient	.012
		Sig. (2-tailed)	.912
		N	81
	Surface approach	Correlation Coefficient	.319**
		Sig. (2-tailed)	.004
		N	81
	Deep strategy	Correlation Coefficient	-.071
		Sig. (2-tailed)	.550
		N	74
	Surface strategy	Correlation Coefficient	.296*
		Sig. (2-tailed)	.011
		N	74
	Deep motive	Correlation Coefficient	.052
		Sig. (2-tailed)	.643
		N	81
	Surface motive	Correlation Coefficient	.253*
		Sig. (2-tailed)	.030
		N	74

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 172

An interesting relationship between approach to learning and the usefulness of various learning resources was also observed in the data collected from the four case studies. This indicated a significant relationship between students who tended towards a deep approach to their learning and a high usefulness rating for Lectures, textbooks and their own notes (Table 173). A very different relationship was observed for students who tended towards a surface approach to learning, where the strongest relationship observed was between surface approach and the usefulness of borrowed notes.

Comparison of Approach to Learning (R-SPQ-2F) and the Students' Learning Resource Preferences

			Deep approach	Surface approach
Spearman's rho	Lectures	Correlation Coefficient	.255*	-.149
		Sig. (2-tailed)	.022	.185
		N	81	81
	Textbook(s)	Correlation Coefficient	.139	-.051
		Sig. (2-tailed)	.219	.652
		N	80	80
	EDEC computer package	Correlation Coefficient	.057	-.012
		Sig. (2-tailed)	.613	.919
		N	81	81
	Own notes from lectures/labs	Correlation Coefficient	.304**	-.078
		Sig. (2-tailed)	.006	.489
		N	80	80
	Borrowed notes from someone else	Correlation Coefficient	.035	.220
		Sig. (2-tailed)	.761	.053
		N	78	78
	Discussion with tutor/lecturer	Correlation Coefficient	-.027	.196
		Sig. (2-tailed)	.813	.085
		N	78	78
	Discussion with other students	Correlation Coefficient	-.211	.043
		Sig. (2-tailed)	.058	.705
		N	81	81
	Other resources	Correlation Coefficient	.122	.114
		Sig. (2-tailed)	.410	.439
		N	48	48

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Table 173

The students' comments from the questionnaires did not show any discernable evidence of conforming to a pattern with regards to deep or surface learning, although proportionally speaking, the surface learners tended to be more positive in their comments (Tables 174 to 176).

Comparison of Students' Comments on EDEC and Deep/Surface Approach to Learning

Count

		Comments from EDEC perceptions questionnaire	
		positive comment	negative comment
Deep/Surface approach	Deep approach	5	14
	Surface approach	3	2
Total		8	16

Table 174

Comparison of Students' Comments on EDEC and Deep/Surface Learning Strategy

Count

		Comments from EDEC perceptions questionnaire	
		positive comment	negative comment
Deep/Surface strategies	Deep strategy	5	9
	Surface strategy	3	7
Total		8	16

Table 175

Comparison of Students' Comments on EDEC and Deep/Surface Motivation

Count

		Comments from EDEC perceptions questionnaire	
		positive comment	negative comment
Deep/Surface motivation	Deep motivation	5	12
	Surface motivation	2	0
	Equal	1	4
Total		8	16

Table 176

7.7. The Role of the Lecturer

During discussion with the staff who had responsibility for the courses under evaluation, it became clear that they generally regarded the EDEC modules as a core component of their students' learning experience, while stressing that there were other support mechanisms available to them during the EDEC lab sessions. This invariably took the form of face to face support from the course lecturer or a demonstrator during each lab session, although the level of support varied from institution to institution.

During the first case study, the deficit in time devoted by the lecturer to support for students during the lab session was offset successfully by peer support within the student group. This situation differed from that of the second institution, where support and feedback was given by the lecturer and two demonstrators throughout each of the EDEC lab sessions and subsequent practical labs.

Formative assessment through questioning of students and feedback was also given through a one-hour tutorial session, which immediately preceded each of the EDEC sessions.

The different approach to student support favoured by the second lecturer, led to a reliance on him and his demonstrators as expert problem solvers, when difficulties arose. While this benefited the students, in terms of the immediacy and quality of the support that was offered, it also led to an observable lack of peer to peer interaction during each of the EDEC lab sessions. A different approach to interaction was however observed during the subsequent practical lab sessions, where much more peer support was observable. The difference in students' peer to peer and peer to tutor interactions could be put down to a number of factors, including the fact that they worked at one student to a computer during the EDEC labs and two to a computer during the practical labs. It could also be attributed to the fact that the activity during EDEC labs was perceived as knowledge acquisition, as against the practical labs, which were perceived more in terms of problem solving activity, with practical, testable outcomes.

The approach of the course lecturer during the third case study was to support the students by discussing their general progress on an individual basis, at a single point during each session. Discussion with the lecturer during the sessions indicated that his aim was to gain an opportunity to carry out informal, formative assessment of student progress on an individual basis. The lecturer also considered the EDEC package as being robust enough to allow final year students to work independently, without the need for constant support.

While this format provided the lecturer with an excellent mechanism for formative assessment, the lack of his presence during the lab led to an observable difference in the students' approach and motivation towards the EDEC package. This was borne out in *'on the record'* and *'off the record'* discussion with the students at the end of each session. The role of the lecturer was however more important to the student in defining outcomes (which were formally assessable) and timescales. Some of the students who participated in the third case study were part-time, and were completing the B. Eng degree, while continuing to work in full-time employment. Their approach to EDEC, and the strategy employed by the lecturer was different, in that they tended to use the package off-campus. The course lecturer alluded to the fact that this particular group of students required less support due to their intrinsically high level of motivation to complete the degree, since most of them were sponsored by their employer. They were also all mature students, which created an observably more business-like atmosphere inside the labs than their full-time counterparts. The difference between the first year undergraduates' approach to their learning and that of final (fourth) year students resonated with Perry's (1981) Scheme of Intellectual and Ethical Development (see Appendix U), which related the changing 'world-view' of the learner as they progress through their education. The evidence gathered from a number of measures certainly indicated a shift from the dualistic approaches of new students to the more confident, relativistic and discerning approach of final year students in line with Perry's stages of progression.

7.8. The Role of the Learning Environment

While the learning environment was very similar in each of the case studies, consisting of dedicated computer clusters, there were some notable differences observed during the case studies. Most obvious of these was the role of the size of lab on students' behaviour. A much greater degree of student interaction and peer support was observed in the smaller clusters that were used in case studies one and three than was observed during the second case study. The use of a much larger cluster for the second case study was necessary, due to the number of students in the class.

During my observation of EDEC and practical lab sessions, it became apparent that the level of student interaction was related to the size of cluster and the intimacy of the atmosphere inside them. This was particularly evident in the third case study where peer interaction was high, even though the earlier evidence suggested a generally negative perception of the package on the part of the students.

The most detailed observation of students in the learning environment came during the second case study. By observing them over three EDEC sessions and three practical labs, a discernable difference in their behaviour was observed. While both the EDEC and practical lab sessions entailed working on a computer in a similar size of lab, a much higher degree of peer interaction was observed during the practical labs than that which was observed during the EDEC labs.

Although the students worked individually during the EDEC sessions and in groups of two for the practical labs, the degree of interaction during the practical labs moved some way beyond peer to peer interaction within the groups. This may be attributable to the practical lab layout, or even the furniture within the lab, which was more like a physics or chemistry wet lab than a computer cluster. One could speculate that the students were exhibiting a more possessive approach towards the computers inside the EDEC cluster than in the practical lab due to the general nature of their other use (e.g. e-mail, surfing the Web etc.). The communal work benching within the practical lab certainly led to a more cooperative environment, with a far higher incidence of movement during the lab when compared with the EDEC lab that had individual computer workstations.

7.9. General Discussion

Although the use of Web-based material such as EDEC can offer benefits to the learner in terms of the delivery of rich and interactive media, the importance of appropriate course design that facilitates a rounded and multi-modal learning experience cannot be underestimated. Observation of students' use of EDEC during the first three case studies indicated the need for more effective integration of the resource within the wider learning environment. This led to a lack of contextualisation of the learning attained through EDEC and the subsequent practical labs.

It was interesting to note that there was a strong relationship between the students' year of study and their overall perceptions of EDEC (Table 177).

Comparison of Year of Study and the Students' Overall Perceptions of EDEC

			Year of study
Spearman's rho	Overall, I liked using the system.	Correlation Coefficient	-.524**
		Sig. (2-tailed)	.000001
		N	81
	I would use this system again in my studying.	Correlation Coefficient	-.364**
		Sig. (2-tailed)	.001
		N	81
	I would recommend the system to other students.	Correlation Coefficient	-.266*
		Sig. (2-tailed)	.016
		N	81

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 177

It is possible that these findings were related to the changes that the individual learner goes through as they develop from '*dualistic*' to '*commitment*' phase identified by Perry (1970, 1981). The third and fourth year students may have matured to a point where they were more willing to make critical judgements on resources and the learning environment based on their own learning preferences and experiences. Studies that have used Perry's scheme within an engineering education environment (Culver & Hackos, 1982 and Pavelich & Moore, 1996) have highlighted the need for a balance to be struck between challenge and support in creating a learning environment which enables students to successfully develop as critical thinkers. They achieved this through careful curriculum design that sought to avoid the use of single answer problems, which may restrict learner development to within the dualistic stage. Instead they specifically designed a curriculum which was intended to challenge students through the use of problems that were considered to be one or two levels above the students' present stage of development while maintaining learner motivation. The EDEC package appeared to fall into the trap of locking students into a dualistic stage, which may explain the largely critical perceptions of third and fourth year students to the package.

There was further evidence of this during the observation of the students, which indicated a rather goal-orientated approach to the package. The first example of this came in the lack of time spent by each student in familiarising themselves with the interface and its functionality prior to engaging with the theoretical content. It was also evident in the very linear approach employed by most students as they worked through the package. Their behaviour however needs to be set against the fact that most students increased their learning in the topics covered by the package. There was a perception that many of the students regarded the package as a learning hurdle to be jumped over, rather than a learning device in its own right. An indication of this emerged from the total time that students spent on the package. Although the sessions were timetabled to last for between two to three hours, the students had generally completed the package within sixty to ninety minutes with little learning evident beyond this.

The observation of the students during all four of the case studies indicated a number of issues regarding the processing of on-screen information and the conflicting demands of the simultaneous processing of animated and textual content. On occasions, this effectively led to conceptual processing of animated media from the first and final screen frames alone, as students struggled to process the continuous stream of information. This led to observable problems with subsequent recall during question screens, as was discussed in detail during the final case study. While the user interface and system navigation was intended to be simple and consistent, the initial internal evaluation of a number of modules developed at different sites showed varying approaches to the user interface and navigation (see chapter 1). The sequential design of the EDEC interface lent itself to a linear approach which may have deterred students from returning to screens that they had already visited. This led to frustration among some of them, as they moved from conceptual processing through animation screens to question screens with no easy method of reviewing specific areas of content without completely reviewing the animation.

Chapter Eight

Conclusions Drawn from the Research

8. Introduction

In carrying out this evaluation of students' use of the EDEC package, a number of issues were raised regarding the ability of the package to deliver effective learning and the perceptions of the students who used it. Although the findings were specific to the use of EDEC, it was anticipated that a number of the project's recommendations could be applied generically to the use of any Web-based multimedia package. This was particularly the case for findings relating to the user interface and the use of animation. While the pre/post-test and confidence log data clearly indicated that some learning had taken place, there is a case to be made for this being in spite of the shortcomings of the package itself, as was most clearly highlighted during the fourth case study.

The following sections of this chapter will outline the key findings of the research and go on to discuss these with reference to the literature and will make recommendations for good practice in the development and use of Web-based learning resources.

8.1. Key Findings of the Research

The key findings obtained from the research relate to the testing of specific hypotheses during the first three case studies and the detailed analysis of students' processing behaviour during the fourth. The main findings were:

1. **Performance in Pre/Post-tests and Student Confidence**

There was no evidence to suggest a relationship between cognitive style in either the organisational or sensory dimensions (as derived through the Cognitive Styles Analysis test) and performance from the three pre/post-tests carried out during the second and fourth case studies. Similarly, there was no relationship established between approach to learning (derived through the Revised Study Process Questionnaire) and performance using the EDEC package. There was also no evidence to suggest that student confidence over a number of topics covered by EDEC during case study three was influenced by either cognitive style or approach to learning.

2. Students' Perceptions of EDEC

Although there was evidence to suggest a positive relationship between deep learning tendency and perception over a number of variables, there was no overall pattern of evidence to suggest a relationship between cognitive style and the students' perceptions of EDEC. There was also evidence to suggest a relationship between perception and the students' year of study, with responses becoming progressively more negative from first to fourth year. While a majority of the students found EDEC useful to their learning the results from the Learning Resource Questionnaire clearly identified a preference for a traditional lecture and note-taking model of learning. These findings tend to concur with those of Sabry and Baldwin, (2003), who found mismatches between student perceptions of particular resources and methods of interaction and actual usage or observed behaviour.

3. Students Processing Behaviour Using EDEC

The design of EDEC tended to promote a linear, goal-orientated approach to its use. This tended to limit the use of feedback loops and reflective behaviour by some students, who typically took a trial and error approach to answering questions. The design of the interface, with regard to the inputting of answers on-screen proved to be non-intuitive for many students. This caused problems with data entry and had a resultant deleterious impact on some students' conceptual understanding. On a number of occasions during the fourth case study this led to students' questioning their previously correct understanding of the theory being tested.

The lack of any ability to control the speed and duration of animations led to the ineffective processing of information in the case of some students. This resulted in a breakdown in their conceptual recall, as they were unable to 'chunk' the information being delivered. The evidence from the fourth case study suggested that this contributed to a degree of frustration among the students, which had a de-motivating effect on them during their use of the package and led to a truncating of the idealised procedural models. This proved to be particularly evident for the more complex, problem solving screens (model 4 screens).

The linear design of the EDEC package was observed to encourage a goal-orientated approach to its use. While the predictability of the package structure was designed for ease of use, familiarity with the structure led to some students skimming over demonstration material in favour of question screens. This led to a breakdown in the learning process, where students were required to initiate feedback loops to review animations and chose not to do so. In turn, this promoted a trial and error approach to questions. There was evidence to suggest that the students perceived EDEC as little more than an assessment interface in the case of modules such as '*Number Systems*'. Due to a combination of predictable structure and the use of single example questions for particular topics, the students merely worked towards the answering of questions, often using trial and error to demonstrate understanding of a particular concept, or skimming over animated demonstrations to get to the question. This led to a lack of reflective behaviour and provided no opportunity for the reinforcement of conceptual knowledge or extension work through multiple examples.

The relevance of these findings will now be discussed with reference to both stakeholders and factors associated with the promotion of effective learning.

8.2. Cognitive Styles, Approach and the use of Inventories

The findings from this research have consistently indicated little or no relationship between cognitive style and students' perceptions and processing behaviour when using the EDEC package. This concurs with a number of other studies that have failed to demonstrate any clear link. A growing number of authors have considered the impact of cognitive styles on the use of various Web-based resources (Spence and Tsai, 1997, Chou, 2001, Federico, 2000, Hong, 2002, Ghinea & Chen, 2003, Graff, 2003 etc.). Their findings more often than not proved inconclusive and sometimes contradictory with regard to the relationship between style and resource use over a number of variables. Where significant findings have been achieved, they often lack consistency or are fragmentary; at times leading to bold claims being made on piecemeal evidence. Parkinson and Redmond's (2002) study for example found a strongly significant link between Riding's wholist/analytic cognitive styles dimension and student performance using CD-Rom. However they found no similarly significant relationship between the field dependence/independence dimension and performance using Witkin's Group Embedded Figures Test (GEFT) with the same intervention. While the authors found no relationship between Riding's verbaliser imager dimension and performance during their study, they did find a significant relationship in a subsequent similar study (Redmond, Walsh and Parkinson, 2003) leading to their calling into question the veracity of Riding's test. In general this study, along with others, would suggest that while it may be important for the developer and the teacher to be aware of the factors which are associated with learning and cognitive styles, it is perhaps more important for them to offer engaging stimulus through any resource which motivates and challenges the learner.

Since I have completed my research, there has been some debate regarding the reliability of the Cognitive Styles Analysis test, which Peterson, Deary and Austin (2003) in particular, have called into question. Their research demonstrated a degree of unreliability in the results obtained through testing of a sample of fifty students in a pre/post-test situation. The results alluded to unreliability issues in the verbaliser/imager dimension, while the results for the wholist/analytic dimension remained stable over both tests. These claims instigated a strong defence of the test from Riding (2003), who cited the relatively small sample size and short time between the initial test being administered and re-administration as contributing factors to the reliability issues raised. While Rezaei and Katz (2003) also raised reliability as an issue with the CSA test, they found that the test had a more effective structure and theoretical underpinning than many other inventories. Coffield et al's (2004) systematic review of the literature on learning styles concluded that the use of off-the-shelf learning and cognitive styles inventories, which often have a tendency to be '*unreliable*' can lead to '*mindless and atheoretical empiricism*' and went as far as to suggest that, '*some order will, sooner or later, have to be imposed on the learning styles field from outside*'. On reflection, and as someone who was initially attracted to the ease of use and academic '*sex-appeal*' of such instruments, I now find myself in agreement with Coffield et al's sentiments.

The R-SPQ-2F results indicated that those students who tended towards a deeper approach to their learning were more likely to be positively disposed to EDEC than their surface counterparts. While there was statistically significant evidence to support this claim, a measure of caution is required when we consider the profiles of the students in the final case study (who were predominantly deep tendency) and the very different approaches to EDEC that were observed. If anything, this highlighted the need for the researcher to balance ease of data collection with appropriate methods that can get beneath the surface of what is being learned. In this regard, the final case study proved to be both illuminating and confounding, as I observed classic surface and extrinsic behaviour from some students who had profiled as having a deep learning tendency. One needs to factor into this the fact that these students were operating within a controlled environment, with no assessment pressure as an outcome of using their EDEC, although the methods used did offer a fair degree of triangulation, allowing a more detailed profile to be developed for each of these students.

8.3. Wider Conclusions Drawn from the Case Studies

During the first three case studies, it became apparent that the pedagogical approach of each lecturer had an important role to play in defining the learning experience using EDEC. While the same resource was used at each of the first three institutions, I observed very different approaches to its use and different expectations on the part of the lecturers. There was evidence through observation and interviews to suggest that pedagogical approaches intuitively differed according to the maturity of the learners.

The observations carried out during the research indicated that the relationship between lecturer and student implicitly developed in line with Perry's scheme, with the lecturer adjusting support and expectation as the student developed as a learner. A greater degree of support in the form of reassurance and validation of learning was required by the first year students in case study two than by the fourth year students in the third case study, who were more critical of the EDEC package, but at the same time dealt with their learning requirements in a more independent and confident manner.

The literature would suggest that the structured nature of the EDEC interface and its materials would tend to support those students with a wholist predisposition, who tend to prefer a structured approach to the delivery of material. This was not apparent through most of the analyses of students' perceptions of the package from case studies two and three. There was however a statistically significant relationship shown between organisational cognitive style (wholist/analytic) and students' perceptions of the usefulness of the package (corr. coeff.= -0.309, p=0.049) and a near significant one for their perceptions of how well EDEC had prepared them for the subsequent practical labs (corr. coeff.= -0.315, p=0.070).

When the students' perceptions of the navigability of the package was considered against cognitive style, there was no discernable link established between either style dimension and navigability. This concurred with Huang's (2003) findings, which compared efficiency of navigation and cognitive styles using the Group Embedded Figures Test (GEFT). The lack of any discernable relationship between sensory cognitive style and the students' perceptions of EDEC was interesting, and suggested that sensory preference had no bearing on any of the variables tested (confidence, performance, perception and resource preference). This contradicts Riding and Douglas's (1993) findings using the CSA test and different combinations of computer-based presentation. Their study found that imagers were more likely to prefer the combination of text and images than verbalisers.

The preference that was shown for a more traditional face to face approach to learning through lectures and contact with the course lecturer (see chapters 4 to 7) concurred to an extent with Shaw and Marlow's (1999) findings, which showed a similar link, particularly in the case of students with a 'theorist' disposition from the Honey and Mumford Learning Style Questionnaire (LSQ). There was also a degree of concurrence with the statistically significant findings from this research, where students with a deep tendency on the R-SPQ-2F scales displayed a preference for more traditional learning methods (lectures, textbooks, lecture notes). However, it is important to stress that the findings from this research showed no link between cognitive style and approach to learning whereas Shaw and Marlow's work did. It is also worth stressing that those students with a deeper tendency were typically more positively disposed to the EDEC package than their surface counterparts. It could of course be speculated that this was predictable, as deeper learners would be more likely to engage in the learning process irrespective of the resource.

While the repeating structure of the EDEC modules was intended to benefit familiarisation with the package, its consistency may have had an impact on the students' motivation, as evidenced during the think-aloud sessions. This concurs with Malone (1981) and Dunn, Dunn and Price's (1989) assertion that a degree of uncertainty in the structure and use of the learning environment can elicit a higher degree of intrinsic motivation among learners. It could be argued that the modules provided a useful insight into the topics covered by them, although they also tended to promote a very behaviourist approach to problem solving. This became clear in the students' approach to the Number Systems module where a stimulus response approach was adopted. This led to some students taking a trial and error approach to multiple choice and drag and drop questions. A number of students were also observed to have ignored feedback to review an earlier topic when they got a wrong answer, because they knew that they could simply move on to the next topic and were eager to complete the module. One way around this would be for the developer to lock the student in to a particular topic until they have demonstrated a degree of proficiency before they can access the next topic. This wasn't the case for any of the EDEC modules that were evaluated. The fact that some modules contained no more than one open question example for key topics, after a single demonstration of the concept, with no supplementary or extension questions led to limited conceptual understanding at times. In this regard, it becomes difficult to justify the EDEC modules as the sole resource for the topics covered.

8.4. The Web and Engineering Education

Engineering education relies on the learner being able to process specialist information which is often communicated both graphically and textually. Discrete disciplines within the engineering field also rely on the learners' ability to understand and effectively process complex symbolic language as a precondition of learning itself. The use of multimedia is something that has proved beneficial in other studies such as Hill et al (1998), where animation and other multimedia were used effectively in the teaching of phase diagrams for 1st year engineering undergraduates. The circuit diagram shown in Figure 34 clearly highlights the complexity of symbolic language used in electronics education.

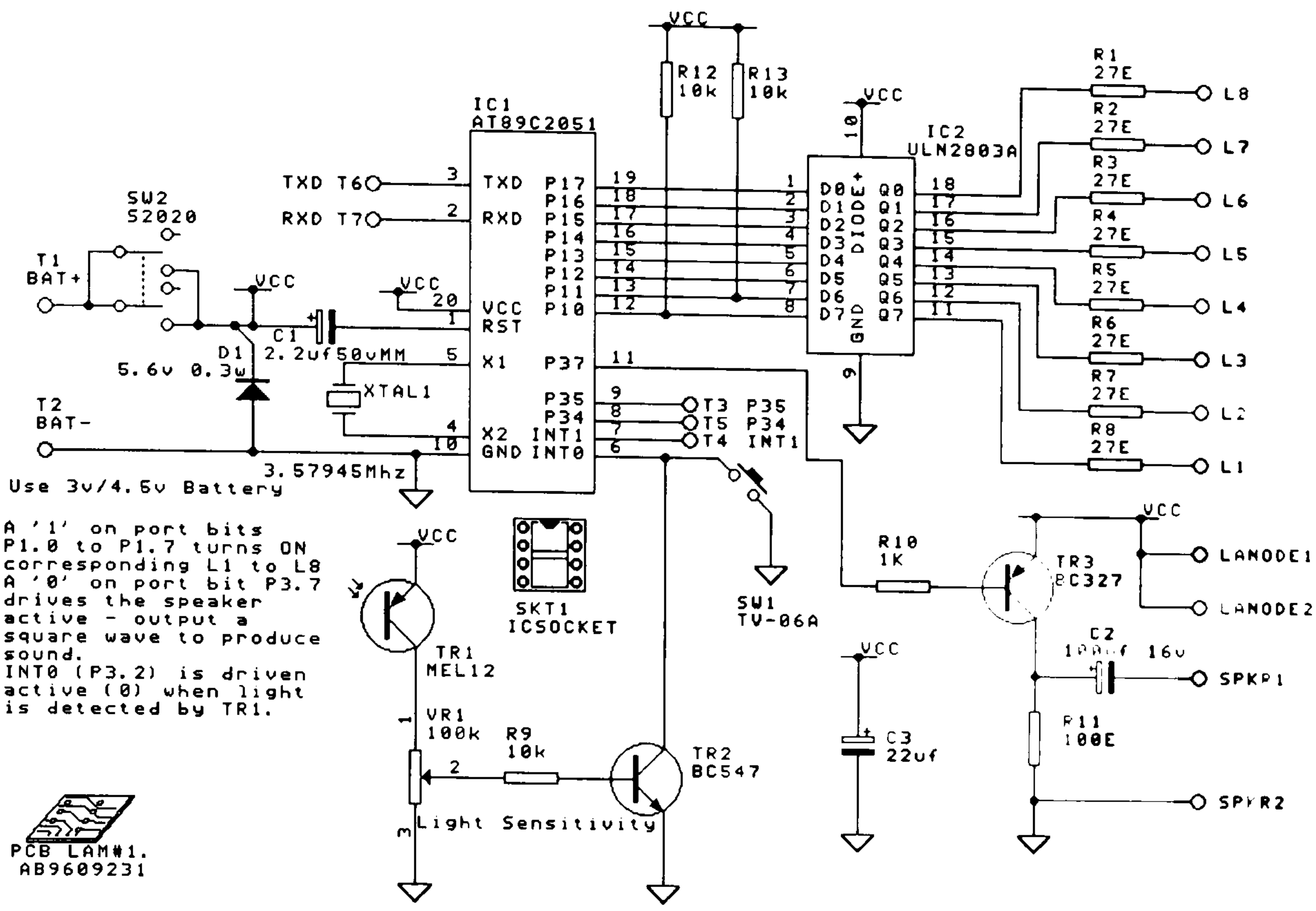


Figure 34

The use of simulation software as well as animation gives the developer an opportunity to illustrate the effects of changing parameters or time on an electronic circuit, in a manner which would be impossible through traditional printed media. This gives the learner the opportunity to expand upon the learning offered by static imagery and develop a stronger understanding of the underlying conceptual theory through, for example considering the animation of current flow within a circuit, or the effects that changing a component may have on the circuit. There are clearly specific applications for multimedia-rich resources in engineering educational environments, that can be highly effective in enhancing students' learning experience. The EDEC package used the principle of animation to demonstrate, for example, the transfer of data in a computer system, thus giving the student the opportunity to see a static diagram develop in a manner which is more analogous to the actual transfer of data in a real system. This may also be said to benefit the student through contextualisation of the concept.

A number of studies have considered the effects of imagery on the learner and highlighted visio-spatial skills, information processing strategies and metacognition as influencing factors on the learner's ability to form meaning from imagery (Kirby, 1993, Winn, 1993, Rieber, 1994, Antonietti, 1999, Cheng, 1999). Winn, in particular, highlighted the specialist loading requirements of engineering imagery, with regards to processing and understanding. Cheng however cautioned against the injudicious use of visual representation as an aid to learning

> *"... the representations used for learning can substantially affect what is learnt and how easy learning occurs; representations can constrain the nature of the conceptual structures that the learners develop and the problem solving procedures they acquire."*

It is therefore important that visual representation through static or animated images is appropriately embedded into the learning resource, in a manner which is understood by the learner and which is appropriately contextualised. It is also important that the learner has the opportunity to easily interact with media in a manner that is not over-reliant on working memory at the application stage, as was observed during the final case study.

The fact that a number of students were observed to be 'skimming' animated media during their use of the EDEC package suggests that the animations were more likely to have been processed as static images. This on occasions led to a breakdown in the student's conceptual understanding, when they were asked to recall information delivered by animation. Because the test environment embedded within the EDEC modules had no bearing on the students' assessment outcomes, they were treated in a very goal-orientated manner, with a fair degree of evidence of trial and error taking place. It also led to some students ignoring feedback from the system when they input an incorrect answer to a question. The importance of the learning activity as a whole is highlighted here, as the EDEC modules were generally used as a precursor to some other activity, particularly during case studies one and two. It could be said that this was more likely to promote a goal-orientated approach, where the students' saw little relationship between the modules and the subsequent practical activities due to the timing of their use. The modules were used in a more constructivist manner during the third case study and although these students were generally less positive in their perceptions of EDEC they were observed embedding knowledge from EDEC more effectively in the wider context of the overall activity. This led to modules being accessed as required, in lieu of knowledge acquisition as a precursor to some other activity. It appeared, during the second case study in particular, that many of the students failed to relate the knowledge acquired through EDEC to the practical activity that followed.

8.5. Final Conclusions

At the outset, I was interested in the role of cognitive style and its relationship with learning through Web-based media, with the presumption that the method of delivery may benefit certain cognitive styles more than others. The idea of adaptive computer and Web-based instructional systems seemed equally attractive for optimising learner performance. As such, the research provided little evidence that would lead one towards the development of resources, which centre on cognitive style. In fact, I would suggest that the development of adaptive learning resources, which rely heavily on the veracity of inventories such as the Cognitive Styles Analysis test, may actually prove harmful to the learner in some circumstances.

The results from the Revised Study Process Questionnaire (R-SPQ-2F) provided stronger evidence of individual differences and relationships with the media delivered by EDEC. With this in mind, one would perhaps promote the development of educational resources that take cognisance of the individual learner while challenging the approaches and strategies which he or she applies in order to promote a more effective and 'rounded' learner overall. This may provide better preparation for a non-adaptive real world.

The evidence from the research indicated a number of problems with the processing of animated media. The continuous nature of the animations was largely responsible for this, inhibiting the students' ability to process information into working memory through 'chunking' techniques. As such, it helped to demonstrate that limited short-term recall due to processing problems can result in a goal-orientated approach to a package such as EDEC can result in a limited learning experience overall.

In general the research achieved many of its experimental aims, although the practicalities of carrying out the research in a number of different institutional environments led to some difficulties with regard to the consistency of the methods employed. It also led to some problems with what was initially hoped would be an accumulative sample size across methods, although the indications provided through the testing of the hypotheses did have a degree of uniformity and robustness.

It is important to stress the benefits that were achieved in taking a complementary approach to data gathering. While reliability issues can arise from the use of quantitative measures alongside qualitative ones, the use of measures such as think-aloud combined with interview offered a thread, which could be followed and triangulated with other data, such as observation and screen capture, at any stage during the student's use of EDEC. Thus, where conflicts did arise, they were often more easy to rationalise through the analysis of qualitative data which offered a rich narrative in support of the evaluation process.

It would have been useful to have been able to follow the study through to the exploration of the data alongside final course marks, which may have been linked to assessment methods, although this wasn't feasible for a number of reasons, including differences in approach to assessment and third-party access to results.

Chapter Nine
Recommendations and Future Research

9. Introduction

This chapter will relate the key research findings to a number of recommendations for anyone interested in the development or use of resources such as EDEC in support of engineering education.

9.1. Recommendations for Resource Development

The study clearly highlighted shortcomings in the design of the EDEC interface and a lack of consistency of approach between the participating institutions. The evidence that was available to me suggested a lack of formative evaluation with key stakeholder groups prior to the software's introduction. Discussions with development staff at two participating institutions also revealed that much of the design process employed in the development of the EDEC package was 'intuitive' and at times entailed little more than the repurposing of existing course materials which had previously been delivered as overhead slides.

This lack of a clear and consistent development strategy no doubt contributed to the problems that have been highlighted during this thesis. The adoption of a clear and common design philosophy, coupled with a systematic approach to the development and testing process may have alleviated or eradicated some of the package's inherent shortcomings. Boehm's spiral model (Section 1.2) is worthy of recommendation for its incremental approach to the development process and more importantly its reliance on mutuality throughout the development and testing phases.

It was evident through discussion with the students that a number of them considered the visual interface important to the learning experience. Some cited the generic approach taken by Microsoft in the visual interface for their Windows™ operating system and other commercially available software as an issue which affected their perception of the EDEC system's navigability as well as aesthetic quality. Some regarded the EDEC interface as *'dated'*, and little more than an *'electronic book'*, which affected their wider perceptions of the package. While developers may wish to stamp their own authority and style on the design of the user interface, it is important to be aware that this may inadvertently impose an additional cognitive burden on the learner, due to their cognitive approach to using other software packages. This in turn may influence the learner's perception of the quality of the resource, even though the two are not necessarily related. The design of the EDEC interface prohibited the kind of easy maintenance that would be available though an HTML website for example. This would have allowed quick and effective changes to the interface, thus potentially extending the lifespan of the resource.

Similarly, the use of streaming technologies can provide an effective solution for the delivery of large file sizes over the Internet, by buffering the files and delivering the information only as it is required. Software such as Adobe Shockwave™, Realplayer™ and Windows Media Player allow 'streamed' media, although this can require the user to download and install a 'plug-in' or other software to facilitate the process. This was found to be problematic during one of the two focus groups which were held during the third case study, where a number of students highlighted problems with downloading the required plug-in for Authorware™. The need to download additional software may certainly inhibit off-campus use of Web-based learning resources, as the learner may have difficulty in locating and downloading the additional software or may lack the motivation for doing so. Although authoring packages such as Adobe Authorware™ are attractive to expert and non-expert Web developers, there are potential benefits in the use of standalone resources, such as Java Applets, which generally require no additional software on the part of the user.

While the research showed no discernable link between the learner's cognitive predisposition and the effects of multimedia on the user, it highlighted a number of issues that should be considered in promoting good practice for the design of any Web-based learning resource. These include:

1. **Consideration of the arrangement of information on the screen.**
    - Try to avoid the need for processing media requiring conflicting use of the same cognitive processing channel (e.g. text alongside animation). The use of soundtrack in lieu of explanatory text can alleviate this problem as it utilises a separate sensory channel (auditory), although high quality soundtracking can be time-consuming and cost prohibitive for smaller projects.
    - Position information in areas of the screen where it will be less likely to be missed (particularly in the case of interactive links).

2. Use of text

The evidence from the literature suggests that one processes text less efficiently from a computer screen than from traditional resources such as books (Muter et al. 1982, Muter 1996). There was some evidence during this study of students skimming over sections of text in order to engage with interactive elements. It may therefore be beneficial to minimise the use of large sections of on-screen text. Where large amounts of text are required these may be better dealt with as hard copy hand-outs. Alternatively, ensure that on-screen text can be printed out where required.

3. Use of animation.

- Allow as much user control as possible to facilitate a 'chunking' approach to processing.
- Consider the duration of animations to avoid learner distraction or cognitive overload.
- Consider the speed of animation to allow time for processing.
- Avoid mixing large amounts of text with animation as this can lead to ineffective processing.
- Avoid movement in different parts of the screen which relies on the user's peripheral vision and may impair effective processing.

4. Use of interactive elements

- Identification of interactive elements should be obvious and consistent with general Web design conventions.
- Where possible include hyperlinks to external software such as simulation packages and the Internet to promote a more constructivist approach to learning.
- Try to be consistent in the positioning of interactive buttons etc. so that the user can easily identify them as they become familiar with the resource.

Grace-Martin, (2001) acknowledged the need for the courseware developer to understand and design multimedia resources that avoid imposing an unnecessary cognitive load on the learner. He qualified this by highlighting the fact that a degree of cognitive burden may be of benefit to the student in developing memory skills and strategies. This view has some merit, although it is important that a balance is struck, so as not to de-motivate the learner through processing overload as occurred at times with EDEC. This was particularly observable in instances where animated material was delivered as self-run media segments, where the learner had no control over the amount of information being delivered or the speed of delivery. The animations often ran continuously for between thirty and forty seconds, with information being delivered in a number of different areas of the screen and alongside static text. In a number of cases this led to students dismissing the animated material in favour of the on-screen text, thus reducing the original intention of the animation to support the text through contextualisation of a particular concept. In extreme cases this resulted in the students being unable to recall information demonstrated by animation leading to a lack of conceptual problem solving during open question screens. This was also observed with regard to students' note-taking during their use of EDEC which was generally minimal, except in the case of the final year students in case study three. The lack of note-taking during demonstration screens led to subsequent problems with the recall of information during question screens, which required a return to previous screens and had a de-motivating effect on the students. This exacerbated the use of a trial and error approach to question screens; a tendency which has been observed during a number of other studies including (Frenckner, 1996; Henderson, 1999).

The problems that were observed in the students' processing of images and more particularly, animations alongside text, resonated with Samuels' (1970) research into the distracting effects of images that are used to support text and the proximal relationship between the two. Although his work was carried out with young children, it highlighted the need for the learner to develop an internal image and therefore meaning from images for effective processing into memory to take place. His work also highlighted the deleterious effect that additional text can have on this process. There were numerous instances of students skimming over animated media or starting an animation as they took notes from accompanying text. This had obvious implications for recall, as was observed during the final case study. It is therefore important that the software developer is aware of the positioning and balance of static and animated images against text, as well as the processing complexity of the images, if they are to properly support the learning experience. Dwyer's (1978) work with adult subjects highlighted the need for sufficient time to be given to the processing of information delivered through imagery, if effective learning is to take place. In the case of animated imagery, this becomes even more important due to the increased processing load. Rieber's (1994) argument that static and animated images should only generally be used if they are offering learning which text alone cannot provide is a persuasive one in this regard. The initiation of animation within a separate window which contains no text would provide a simple method for separating the two thus focussing the student's attention towards the processing of the animated content without the distraction of text.

9.2. Recommendations for the Learning Environment

The physical learning environment had an unexpected impact on the way in which the students approached their learning during each of the case studies. The layout, size and usage of computer clusters all played a part in defining the dynamics of the learning environment and in particular, the level of interaction and peer support that was evident. The use of computer clusters for Web or computer-based learning is now commonplace across college and university campuses and there has been a degree of research carried out with regard to best practice (Eagles, 2001[1][2]). Their use as a means of communication through, for example, e-mail, as well as for recreational purposes may have a bearing on the students' perception and use of a particular environment.

During one of the case studies, it became evident that some students perceived the computer cluster's use in general terms, using the computers for e-mail and surfing the Internet during timetabled EDEC sessions. This may have been exacerbated by the fact that students on other courses would sometimes be using computers during the sessions. There may also be a link with student motivation, as it was generally students who either arrived late for the EDEC sessions or finished quickly who would engage in this type of unrelated activity. This observation was in line with Hills and Argyle's (2003) findings that the, '*...use of the Internet can be regarded, at least in part, as a form of displacement activity, engaged in when there is nothing else to do or when the task in hand is not especially attractive*'.

The size of clusters also proved to be important to the learning experience, with smaller clusters being observed to have facilitated a greater degree of peer to peer interaction among students. This was particularly evident during the second case study, where students were spread over two clusters; one containing around fifty computers and the other around twelve. Observations of each session indicated a marked difference in students' approach between the two clusters, with a far higher degree of peer to peer interaction evident in the smaller cluster. A contributing factor may, of course, have been the make up of the particular group of students who chose to use the smaller lab for each session.

Over the course of the case studies, it appeared that smaller computer clusters that were purely dedicated to timetabled use were more conducive to learning and peer to peer interaction. This observation has to be countered to an extent by the evidence from the students in the large practical lab during the second case study, where a high degree of peer to peer interaction was observed. It therefore has to be speculated that the tasks themselves provided the motivating factor. In the case of the practical lab environment, the students were more likely to engage in group problem solving based on the requirements of the tasks given to them. The tasks themselves therefore created an environment, which allowed the students to develop a shared conceptual understanding through the completion of the tasks. This was not the case with EDEC, where the same students typically perceived the learning environment and tasks within the modules as being individual. During the second case study, the transition from passive learning through EDEC (with no clear outcomes) to active engagement during the practical labs, seems likely to have been the greatest contributing factor to the students' approach to their learning, and interaction with other students. In this regard, the model employed by the lecturer during the third case study may be seen to have promoted the integration of EDEC most effectively within the wider learning environment. Although these students were the most critical of EDEC, there was a greater sense of independent learning taking place during their sessions, with a higher degree of peer to peer interaction than was observed during the first two case studies.

The less formal perception of a traditional electronics lab may have contributed to the change in students' approach to their learning. Layout and furniture may also play a role here, as students appeared less inhibited in moving around the practical lab than in the computer cluster, even though they were still in fact using computers. The findings from the first three case studies would indicate that in order to design a constructive learning environment, which promotes peer to peer interaction. a number of factors should be considered:

1. Organise computers within a cluster to promote more effective peer to peer interaction.
2. Try to encourage an environment which is focused towards the learning intervention and avoid extraneous activity such as checking e-mail and Web surfing which is unrelated to the task.
3. Support the learner through alternative learning methods and resources where possible.
4. Where appropriate, support the learning intervention through the contextualisation of its use as, for example a precursor to practical activity.
5. Try to create an environment which stimulates student responsibility for learning while offering an appropriate level of challenge to promote learner development in line with Perry's scheme.
6. Consider the use of small groups for knowledge acquisition activities such as EDEC to promote the cross-pollination of conceptual understanding.

With regard to setting an appropriate pedagogical ethos for the learning environment. Felder's work, which espoused a form of *'learning triangulation'* through a diverse approach to resourcing and interaction is worthy of recommendation. It goes without saying that any educator should consider such an approach in order to facilitate learning which is independent of style or strategy wherever possible. This of course requires careful consideration when it comes to curriculum development, since a diverse pedagogical approach to resourcing, delivery and interaction requires rigorous planning, staff support and comprehensive ongoing evaluation.

9.3. Assessment Issues and Curriculum Change

There are those who believe that assessment is no more than a necessary evil in education. This view is often derived from concern at the role of politics in education. where assessment and examination are often misused in the name of what are euphemistically called 'standards'. Heywood (2000, p.16) astutely highlighted the effects of the politicisation of university admissions on the secondary curriculum and approaches to learning and teaching, which is driven by the demand for 'results'.

> *"In these circumstances there are pressures for good results and unless the examinations (tests) and grading systems are designed to enhance learning their backwash effect can be limiting on learning – if not positively harmful."*

If educators are to provide deep and constructivist learning experiences for the student, then the methods of assessment have to be sensitively considered. To this end, the EDEC package as a standalone resource may not promote the kind of deep learning experience without careful embedding into a wider learning experience. This was particularly evident during the final case study where the students had no vested interest in the content of the Number Systems module and therefore merely wished to get through it. It was also evident in their approach to note-taking during their use of the package, which was limited to scribbled calculations in support of the current task as against longer term support. This limited subsequent recall of process and conceptual information, as was observed during the practical lab sessions during case study two. The lack of structured note-taking and its effects on recall, highlights the importance of combining computer based resources with other methods which encourage the development of structured notes that can support of future learning. Otherwise, resources such as EDEC can be perceived as having no context within the wider learning environment, which may limit their effectiveness.

The lack of reflective behaviour engendered by the EDEC package was particularly disappointing to observe. The user interface without a doubt contributed to the lack of reflective behaviour, with students typically endeavouring to progress to the next screen where possible and often without any overt signs of reflection on the concept under demonstration. The advent of online learning environments such as WebCT, Blackboard and Moodle offers the educator the opportunity to embed resources such as EDEC within a wider learning environment that can be supported by reflective tools such as online journals, fora and wiki. Using such tools can provide effective learning support beyond knowledge acquisition, which, if used in conjunction with a resource like EDEC can provide the learner with a deeper and more reflective learning experience. These tools can also provide a valuable social context to online learning that can enhance individual and group learning when placed alongside other resources.

Although the traditional lecture format was consistently popular with most students during the research, the knowledge transfer model that it promotes could be said to offer a narrow learning experience. This can lead to an assessment regime which goes little beyond the regurgitation of the lecturer's knowledge. Cowan (1983) highlighted his concern at what many would still regard as the traditional approach to engineering education and the transfer of knowledge from lecturer to student:

> *"My conclusions: confirmed by similar findings in fluid mechanics and electrical circuit theory are: Understanding is highly individualised. It can be nurtured in properly designed learning situation. Without special attention, however, it will atrophy leaving even able graduates to be merely number crunchers."*

His findings from as far back as 1983 demonstrated the tangible benefit of taking a qualitative and reflective approach to teaching through 'self-study' packages in developing a deeper understanding of engineering and scientific concepts while taking responsibility for one's own learning. Recent moves towards a problem based learning approach to engineering education (Maskell, D, 1999; Perrenet J. C. et al, 2000, Fink, 2002; Mitchell et al, 2005) is encouraging, with clear evidence to suggest that this approach promotes a deeper and more contextualised learning experience, which values the qualitative and formative as well as the quantitative and summative. The use of learning technologies within this kind of environment can promote independent and flexible learning, while at the same time developing a reflective approach to the individual's learning, although Shaw and Marlow's (1999) work showed the deleterious affect that the injudicious embedding of such technologies can have on the learning process.

Problem based learning, as an approach, has proved successful in medical degree programmes (Fraser & Greenhalgh, 2001, Norman, 2002, Smits, Verbeek & de Buisonjé, 2002). As a model, it closely mirrors the knowledge acquisition, problem solving and application approach required in engineering education. To this end, the use of computer and Web-based resources, which offer simulation and enhanced support in the acquisition of knowledge, as well as providing a solid context for the application of that knowledge, may be invaluable in the promotion of a deeper learning experience. The move towards an educational environment, which encourages capability through problem solving and contextualised, 'real world' learning scenarios is one that should be welcomed, no matter the method of delivery.

Biggs (1999) highlighted the changing face of higher education in the UK, with a greater proportion of students who see their degree as a *'means to an end'*, as against the more intrinsically motivated student of the 'old' university system. He also highlighted the need for curricular and pedagogical change as a facilitator of learning for this new student population:

> *"Good teaching is getting most students to use the higher cognitive level processes that the more academic students use spontaneously."*

In this regard, a reflective approach to curriculum development, teaching and learning, which challenges and supports the learner, is vital to meet the demands of students within the present system.

9.4. Recommendations for Effective Evaluation

Sanders (2001) described the aim of evaluation as being the development of *'conceptual clarification'*. With this in mind, I will now reflect on the successes and failures of this study. Were the initial aims of the research met? What difficulties, if any were encountered? What would I do differently next time? In carrying out the evaluation of students' learning using the EDEC package, a number of issues became apparent. Firstly, it became obvious that a flexible approach to the core experimental design would be required due to the different learning environments, timescales and data collection opportunities that were available. While this created some problems, not least in terms of the uniformity of the final data set, it did confirm the vagaries of practical 'real world' research. The case study approach to the research gave an excellent opportunity to evaluate the EDEC package in different learning contexts and with students at different stages of their development. This was invaluable, and to a degree offset the problems of experimental design and sample size. The qualitative nature of the final case study provided me with the opportunity to investigate a number of issues regarding the students' use of EDEC in greater detail. While it confirmed much of the observational evidence from the other case studies, it also raised some important issues with regard to the reliance on largely quantitative data in educational research projects without effective triangulation. Although the final case study was carried out in a controlled environment, the insight into the students' use of EDEC, and their approach to conceptual problem solving and processing of media that it provided, became fundamental to the study's findings.

While individual sample sizes were sometimes low, the combined sample would certainly have been sufficient to give reliable statistical results during the testing of hypotheses that were core to the study. This was complemented by the analysis of verbal protocols from a small number of students to provide an insight into the students' behaviour at macro and micro levels. To this end the approach taken in the evaluation of the EDEC package provided a useful, if sometimes conflicting picture of students' approach to the resource.

The use of inventories such as the Cognitive Styles Analysis test (CSA) and the Revised Study Process Questionnaire (R-SPQ-2F) may have to an extent contributed to the conflicting nature of some findings. This was particularly the case with regard to the observational evidence relating to the strategies employed by the students as they used the EDEC package. While characteristically surface behaviour by some students was being observed, their profile through the R-SPQ-2F indicated that they were more likely to employ a deep approach to learning. This exposes a problem with such inventories, where a student may wish to be regarded as a deep learner based on the questions within the inventory, or may genuinely believe that he or she takes a deep approach, although the actual evidence is to the contrary.

This phenomenon could also be related to the particular resource being used. It is perfectly possible that a student who profiled as having a deep approach to learning may take a very surface approach to a resource such as EDEC due to their motivation towards the resource. As has been discussed in chapter two, the non-stable nature of strategy and motivation could indeed lead to this outcome. Having said that, and bearing in mind the findings of this study, it would seem appropriate to recommend a degree of caution in the use of psychometric inventories without a triangulated approach to the research overall and a clear overarching theoretical epistemology.

9.5. Future Research

One important factor that was considered during the development of the conceptual framework but omitted from the experimental design due to time and access limitations was personality. Bearing in mind the potential problems associated with psychometric testing discussed earlier, the administration of, for example, Eysenck's personality questionnaire or Costa and McRae's NEO 5-factor inventory would have provided me with an opportunity to explore the links between personality and the other variables under test. This may have provided a valuable insight into the role of personality, in for example defining the student's perceptions of and motivation towards the EDEC package. Recent research carried out by Zhang (2003) using the NEO 5-factor inventory, interestingly showed evidence of '*conscientiousness*' and '*openness*' traits acting as reasonable predictors of deep approaches to learning and one can see the benefits of considering both. Similar relationships between personality, approach to learning and achievement have been observed by Diseth (2002). Dweck (2000) and Vermetten, Lodewijks and Vermunt (2001) have included goal orientation within their research, alongside personality and approach to learning. These inter-relationships also offer interesting scope for future evaluation studies.

Our aim as educators should be to provide our students with a deep and reflective learning experience, which offers as diverse a range of learning opportunities as possible. It is also important to challenge predisposed styles in order to give the learner a greater 'roundedness' in preparation for future interactions with a world that does not necessarily adapt to the needs of the individual. If we are to achieve this aim, the development and integration of Web-based resources needs to go beyond the delivery and acquisition of knowledge. If these resources are to motivate and challenge the learner they need to offer more than the direct replacement for traditional teaching methods. This research indicated that the EDEC package failed to promote a deep and reflective approach to learning across a number of learning situations. In particular, the developers' '*intuitive*' approach to the use of animation was observed to have impacted users' processing behaviour and recall, leading to a breakdown in the learning process and student motivation due to their difficulties in processing information effectively.

On reflection I would have to agree with the sentiments of Beasley at al (1995) who observed that, '*everyone is different. That's why they should be treated the same*'. They somewhat controversially criticised the propensity for curriculum reform in engineering based on the individual traits and needs of the learner. They noted that while these were worthy goals, they were unlikely to be satisfactorily addressed at individual level, through an over-concern with individual styles and personality types and once again highlighted the need to prepare students for a non-adaptive, non-individualised real world.

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Appendix A

EDEC Evaluation Questionnaire

Student number: ____________________

IMPORTANT INSTRUCTIONS

This questionnaire asks about your experience in using the EDEC software as well as using computers and the Internet more generally in your learning. For section 3 of the questionnaire "The EDEC Package" please only answer the questions in relation to this particular module. Do not include information from other parts of the course.

Please add comments where you feel they are appropriate in the right hand column of each page. These comments can be good or bad.

If you have any general comments to make once you have completed the questionnaire, please insert them below.

General comments

Section 1 – How you learn best

Please rank the following learning resources in order 1-8.
Also tick their level of usefulness to your learning.

What you used to learn	Frequency of use (ranked 1 to 8)	Usefulness of resource					Comments
		Useless	Not very useful	Useful	Vital	Not sure	
Example: Audio program	4			√			Hard to get hold of – wanted to use it more.
Lectures							
Textbook(s)							
EDEC computer package.							
Own notes from lectures/labs.							
Borrowed notes from someone else.							
Discussions with tutor/lecturer.							
Discussions with other students.							
Other resources (please specify).							

For the following statements please tick one box only.

	Never/rarely true	Sometimes true	True half the time	Frequently true	Always/almost always true
I find that at times studying gives me a feeling of deep personal satisfaction.	☐	☐	☐	☐	☐
I find that I have to do enough work on a topic so that I can form my own conclusion before I am satisfied.	☐	☐	☐	☐	☐
My aim is to pass the course while doing as little work as possible.	☐	☐	☐	☐	☐
I only study seriously what's given out in class or in the course outlines.	☐	☐	☐	☐	☐
I feel that virtually any topic can be highly interesting once I get into it.	☐	☐	☐	☐	☐
I find most new topics interesting and often spend extra time trying to obtain more information about them.	☐	☐	☐	☐	☐
I do not find my course very interesting so I keep my work to a minimum.	☐	☐	☐	☐	☐
I learn some things by rote, going over and over them until I know them by heart even if I don't understand them.	☐	☐	☐	☐	☐
I find that studying academic topics can at times be as exciting as a good novel or movie.	☐	☐	☐	☐	☐
I test myself on important topics until I understand them completely.	☐	☐	☐	☐	☐

	Never/rarely true	Sometimes true	True half the time	Frequently true	Always/almost always true
I find I can get by in most assessments by memorising key sections rather than trying to understand them.	☐	☐	☐	☐	☐
I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.	☐	☐	☐	☐	☐
I work hard at my studies because I find the material interesting.	☐	☐	☐	☐	☐
I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.	☐	☐	☐	☐	☐
I find it unhelpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with topics.	☐	☐	☐	☐	☐
I believe that lecturers shouldn't expect students to spend significant amounts of time studying material everyone knows won't be examined.	☐	☐	☐	☐	☐
I come to most classes with questions in mind I want answering.	☐	☐	☐	☐	☐
I make a point of looking at most of the suggested readings that go with the lectures.	☐	☐	☐	☐	☐
I see no point in learning material which is not likely to be in the examination.	☐	☐	☐	☐	☐
I find the best way to pass examinations is to try to remember answers to likely questions.	☐	☐	☐	☐	☐

Section 2 – Learning from a computer

For the following questions please tick one box only.						**Comments**
How often do you use a computer?	Less than once a month	Around once a week	3 or 4 times a week	Most days	Never used one	
	☐	☐	☐	☐	☐	
How often do you use the Internet?	Less than once a month	Around once a week	3 or 4 times a week	Most days	Never used it	
	☐	☐	☐	☐	☐	
What do you use the Internet for ? **(rank each option 1-5)**	Own use	Course work	Shopping	Project research	Other	
	☐	☐	☐	☐	☐	

Below you will find a range of statements about the structure and design of the EDEC system. Please indicate your level of agreement with each statement by indicating your response on a scale of 1 to 5.

Please circle one number only.

	Strongly disagree	→			**Strongly agree**	
I like to learn using computer packages.	**1**	**2**	**3**	**4**	**5**	
The Internet is very useful to my learning.	**1**	**2**	**3**	**4**	**5**	

Section 3 – The EDEC Package

Below you will find a range of statements about the structure and design of the EDEC system. Please indicate your level of agreement with each statement by indicating your response on a scale of 1 to 5.

Please circle one number only.

Learnability	**Strongly disagree**	→			**Strongly agree**	**Comments**
I could follow the instructions clearly.	1	2	3	4	5	
I quickly became familiar with the system.	1	2	3	4	5	
Parts of the system were difficult to use.	1	2	3	4	5	
The instructions on screen were sufficient when needed.	1	2	3	4	5	
The system helped me if I got confused.	1	2	3	4	5	
Navigability						
It was clear to me where I was in the system.	1	2	3	4	5	
It was clear how to move through the system.	1	2	3	4	5	
I think that the system is generally well structured.	1	2	3	4	5	

Section 3 – The EDEC Package

Below you will find a range of statements about the structure and design of the EDEC system. Please indicate your level of agreement with each statement by indicating your response on a scale of 1 to 5.

Please circle one number only.

Quality	**Strongly disagree**	→			**Strongly agree**	**Comments**
I found that the information was presented consistently.	**1**	**2**	**3**	**4**	**5**	
It was obvious how to use the icons (buttons etc.).	**1**	**2**	**3**	**4**	**5**	
The language was clear.	**1**	**2**	**3**	**4**	**5**	
I could easily read from the screen.	**1**	**2**	**3**	**4**	**5**	
The screen colour did not interfere with my reading.	**1**	**2**	**3**	**4**	**5**	
I thought that the graphics were clear and helpful.	**1**	**2**	**3**	**4**	**5**	
I thought that the interactive elements were difficult to find.	**1**	**2**	**3**	**4**	**5**	
I found the animated elements too fast.	**1**	**2**	**3**	**4**	**5**	
I felt that the animated elements would have been better if I could control speed and stop/start.	**1**	**2**	**3**	**4**	**5**	
The use of images to support text was useful.	**1**	**2**	**3**	**4**	**5**	

Section 3 – The EDEC Package

Below you will find a range of statements about the structure and design of the EDEC system. Please indicate your level of agreement with each statement by indicating your response on a scale of 1 to 5.

Please circle one number only.

Workload	**Strongly disagree**				**Strongly agree**	**Comments**
There was too much information on each page for me to remember.	**1**	**2**	**3**	**4**	**5**	
There was too much information which I didn't need to know.	**1**	**2**	**3**	**4**	**5**	
I got what I wanted from the system quickly.	**1**	**2**	**3**	**4**	**5**	
Likeability						
Overall, the system had an attractive presentation.	**1**	**2**	**3**	**4**	**5**	
Overall, I liked using the system.	**1**	**2**	**3**	**4**	**5**	
I would use this system again in my studying.	**1**	**2**	**3**	**4**	**5**	
I would recommend the system to other students.	**1**	**2**	**3**	**4**	**5**	

Thank you for your assistance

Appendix B

Observation/Student Questions – Notes, Case Study 1

30th January 2002

Instrumentation Amplifier Module – 3hrs duration
Working Sample Size – 23 students

General Notes
- Learning environment – EDEC as a precursor to lab sessions.
- Course lecturer normally available to deal with student questions.

Observations
- Note taking through workbooks applied pretty rigorously by most students throughout session.
- A number of students take a 'trial and error' approach to interactive elements within the material.
- Most students spending reasonable time on each screen to reflect and take notes.

Student Questions
- One student expressed concern that animated elements could be confusing.
- Same student highlighted the usefulness of EDEC workbooks to support each module.
- Most students expressed a clear preference for the EDEC material over other methods of learning such as books.
- Students generally expressed no problems with using the EDEC material over the Web.
- Animated elements linked with play. One student said they were more interesting than static materials.
- Some students highlighted the need in some cases for better user control over animated segments.
- One student indicated the need for better links between screen pages and sections of workbook.
- A number of students highlighted the usefulness of being able to suspend and return directly to the original page. This facility is in fact built into the interface.
- A number of students highlighted the usefulness of being able to switch between Windows (other software) and the EDEC material without having to exit EDEC.
- Many students highlighted the benefits of being able to access the EDEC material on-line at home or in halls.
- A general link was evident between what students needed to pass exams and note taking via EDEC notebooks and learning generally as preparation for labs.
- Animated elements were almost unanimously viewed as a positive benefit to learning.
- More than one student asked for more space for note taking in workbooks, so that all notes would be together.
- Most students expressed no problems with processing animated elements.

Developer Questions
- Darrel mentioned that the design philosophy for his EDEC modules was largely intuitive with regards to animated and interactive elements.
- There was no specific design strategy for the duration, speed and processing of animated elements.

Student Comments

Appendix C

Case Study 1

General Comments

	+ve	-ve		
00029324				
" I find learning through internet very useful and more involved. The whole idea of computer based learning is one of the best things that I've seen the emerging technology bring about. Computer based learning is one to one and is bound to get you fully involved and familiar with what you are learning."				
00084995				
"A few times using the five modules to study I found that it did not offer enough depth i.e. VCO tells you purpose of R_6R_7 on Schmitt to set voltage threshold – but to what? I don't feel the notes works for me – I can be really getting into a topic and then stop to draw when I've taken the key aspects of the graph so this I find very time consuming also copying formula steps down. I learn, understand and would like it written there but able to add/enhance by adding my own notes not to complete the booklet. Sorry prefer lectures."				
01234567				
"Using the EDEC software package is not necessary. Many books in the library are much more useful. I prefer to learn by building the actual circuit rather than learn from a software package."				
01234571				
"The workbooks could do with a bit more room for notes and calculations for interactive elements. A print option might be useful."				
01247203				
"For the foreign student use the EDEC package was very helpful to understand the aim of the course and to test themselves our comprehension. I'm happy and completely satisfied about EDEC package."				
01247592				
"Very good in general but a few things to fix. Animations to be improved (control, speed etc.). Could implement an index/help dialogue box (like in Windows) so if using EDEC we don't remember something we could get the information very quickly!"				

01248003				
"It's my first year in England and it's very good for me. I've more time to understand the aim of the lesson. I can read the slide the time that I need to understand and when I want. So, for foreign student, EDEC package is very useful! In a same time, I can improve my English!!"				
01258769				
"I am very pleased with "the EDEC Package" because it helps me to understand parts of the lectures that were not so clear to me. They are easy to use, and I really appreciate the examples that many times include. Sometimes I would like to be able to print some pages, in order to study away from my computer since I spend too much time in front of my computer."				
01258778				
"I think as far as concern the EDEC module it is a contemporary tool for the Engineers in order to understand the topics which they been teached in classroom. But I believe that a system like EDEC must contain a significant amount of practical advices and informations for example more waveforms at the significant importance points of each circuit, and wave information about what of the stuff that we are read about its been use to the industry. Which is the place of application of the knowledge that engineers has."				
01262522				
"It was the first time I used computer based learning and I did really "enjoy" it, the only thing is that you still need a teacher in order to answer points when questions, and that the software can't provide you."				
01278079				
"I am very happy for using EDEC software. It's very useful package and did give to me the opportunity to learn a lot of things. Its language is clear and I can read easily from the screen. Something very important is that the EDEC program is very well structured. In general EDEC is a very useful package which help me loads for learning new things and remember to me a lot of things as well."				
01288481				
"This EDEC computer based learning is a really good compliment to the lectures. Animations are really helpful for the understanding. Sometimes too much calculations/equations not often helpful. General feeling is really positive, useful material, clean presentation, easy to follow."				

98051028				
"EDEC is a useful, however time-consuming package. I have tended to copy most notes and especially formulas. It would be more useful to work through without any note taking and then have a bulleted summary at the end of each section from which to take notes and formulas."				
99044148				
"The EDEC package is very helpful in my studies. The only problem is that, it is time consuming and quite boring sitting in front of the computer just clicking the mouse."				

Appendix D

Course Deliverer Interview

Case Study Two – 15th March 2002

1. What was your role in the development of this course?
   - **The course was developed as a direct replacement for an existing lecture based course. The material used was 100% transferred from OHP format to EDEC format.**

2. What is the intention of the course in terms of learning?
   - **The intention of the course is to lead the student towards an understanding of how a computer works in terms of information processing and programming. It is intended to support the second year syllabus which relies greatly on the use of assembly language.**

3. What contribution do the EDEC modules make to the course?
   - **Overview/support material as a basis for assembly language labs. Stressed that the material and platform are not a suitable environment for assembly language and programming.**
   - **Lab note hand-out support given to students during assembly language sessions were problematic in that students tended to over rely on the summary definitions within the notes. The course book, although not compulsory to purchase went way beyond the scope of the notes and it was the lecturer's expectation that students use of assembly language also went beyond the lab notes.**

4. What steps if any were taken to integrate the EDEC material into your teaching?
   - **There was never any intention to explicitly integrate the use of EDEC into wider course activity. The use of EDEC was largely based on its replication of course lecture notes.**
   - **A number of approaches to the timing and delivery of the course had been tried in the five previous years, with the present format of three EDEC sessions followed by 3 lab sessions proving most effective.**
   - **The time saving benefits of EDEC was highlighted, in that time savings achieved through the use of EDEC could be passed onto lab sessions which are regarded as the core learning environment.**

5. What could be done (by tutors/system) to make the system easier to integrate?
   - **The importance of appropriate access to computers which allows individual student access was highlighted. This has alleviated timetabling problems for large group (over 50) computer access. In previous years, students worked through EDEC modules in pairs due to insufficient computer numbers. The resource is therefore paramount as it allows individual students to progress at their own pace.**

6. Has the structure of the course evolved over the last 5 years (if so, why)?
   - **The production of all three modules to replace the traditional lectures has led to a stable learning environment over the last five years, since the EDEC modules directly replace lecture notes in this case.**
   - **A reasonable regimented timetabling and supervision of students use of the EDEC material was found to be more beneficial than previous experience whereby the students were given responsibility for the time they spent on the EDEC modules.**

7. What course evaluation has taken place previously?
   - **An in-house evaluation had previously taken place which utilised a control group (traditional lectures) and a treatment group (EDEC modules). The sample**

size was 48 students. The evaluation took the form of a computer architecture quiz.

8. What do you think have been the main benefits to your course of using the system? Prompts: savings in amount of course/tutor time easier/better access to resources for students savings in student time more motivating student experience more effective student learning process improved student work relating to key skills application (how do you know).
   - **The ability to cover the same material in a shorter space of time has freed up time for practical lab sessions.**
   - **The computer-based modules also allow for greater individual support to the student through lecturer supervision and demonstrator support.**
   - **Students have always appeared to be motivated in their use of EDEC. This is borne out in the maintenance of high attendance rates throughout the EDEC sessions.**

9. What do you consider to have been the main drawbacks (costs) in using the system? Prompts: tutor preparation/development time difficulty in accessing computers extra demands by students for tutor support extra time demands on students student browsing and time wasting.
   - **Since the modules were designed as direct replications of existing lecture materials, it was felt that they met the aims of the course very well.**

10. Are there any elements of the EDEC material which could be changed to improve learning?
    - **Doesn't view the EDEC modules or previous lecture format as core to students' learning experience.**
    - **Felt that it was important that students were able to extrapolate and supplement their own knowledge if required.**
    - **Previous experience of the assignment which assesses the learning covered through the EDEC modules and lab sessions has shown that students tend to fill any gaps in their learning effectively.**
    - **Expressed discomfort with having to explain information to students which could be taken from a book. Views the EDEC material as being a representative sample of the information which is required for this section of the course.**

11. Do you have any further comments about the system or its use within your course that you would like to make?
    - **Expressed confidence that under observation, students were more comfortable with the EDEC resources this year than in previous years.**

Course Deliverer Interview

Appendix D

University of Newcastle upon Tyne – 15th March 2002

1. What was your role in the development of this course?
   - **The course was developed as a direct replacement for an existing lecture based course. The material used was 100% transferred from OHP format to EDEC format.**

2. What is the intention of the course in terms of learning?
   - **The intention of the course is to lead the student towards an understanding of how a computer works in terms of information processing and programming. It is intended to support the second year syllabus which relies greatly on the use of assembly language.**

3. What contribution do the EDEC modules make to the course?
   - **Overview/support material as a basis for assembly language labs. Stressed that the material and platform are not a suitable environment for assembly language and programming.**
   - **Lab note hand-out support given to students during assembly language sessions were problematic in that students tended to over rely on the summary definitions within the notes. The course book, although not compulsory to purchase went way beyond the scope of the notes and it was the lecturer's expectation that students use of assembly language also went beyond the lab notes.**

4. What steps if any were taken to integrate the EDEC material into your teaching?
   - **There was never any intention to explicitly integrate the use of EDEC into wider course activity. The use of EDEC was largely based on its replication of course lecture notes.**
   - **A number of approaches to the timing and delivery of the course had been tried in the five previous years, with the present format of three EDEC sessions followed by 3 lab sessions proving most effective.**
   - **The time saving benefits of EDEC was highlighted, in that time savings achieved through the use of EDEC could be passed onto lab sessions which are regarded as the core learning environment.**

5. What could be done (by tutors/system) to make the system easier to integrate?
   - **The importance of appropriate access to computers which allows individual student access was highlighted. This has alleviated timetabling problems for large group (over 50) computer access. In previous years, students worked through EDEC modules in pairs due to insufficient computer numbers. The resource is therefore paramount as it allows individual students to progress at their own pace.**

6. Has the structure of the course evolved over the last 5 years (if so, why)?
   - **The production of all three modules to replace the traditional lectures has led to a stable learning environment over the last five years, since the EDEC modules directly replace lecture notes in this case.**
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   - **An in-house evaluation had previously taken place which utilised a control group (traditional lectures) and a treatment group (EDEC modules). The sample size was 48 students. The evaluation took the form of a computer architecture quiz.**

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   - **The ability to cover the same material in a shorter space of time has freed up time for practical lab sessions.**
   - **The computer-based modules also allow for greater individual support to the student through lecturer supervision and demonstrator support.**
   - **Students have always appeared to be motivated in their use of EDEC. This is borne out in the maintenance of high attendance rates throughout the EDEC sessions.**

9. What do you consider to have been the main drawbacks (costs) in using the system? Prompts: tutor preparation/development time difficulty in accessing computers extra demands by students for tutor support extra time demands on students student browsing and time wasting.
   - **Since the modules were designed as direct replications of existing lecture materials, it was felt that they met the aims of the course very well.**

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    - **Doesn't view the EDEC modules or previous lecture format as core to students' learning experience.**
    - **Felt that it was important that students were able to extrapolate and supplement their own knowledge if required.**
    - **Previous experience of the assignment which assesses the learning covered through the EDEC modules and lab sessions has shown that students tend to fill any gaps in their learning effectively.**
    - **Expressed discomfort with having to explain information to students which could be taken from a book. Views the EDEC material as being a representative sample of the information which is required for this section of the course.**

11. Do you have any further comments about the system or its use within your course that you would like to make?
    - **Expressed confidence that under observation, students were more comfortable with the EDEC resources this year than in previous years.**

Appendix E

Introduction to Assembly Language

Practicals
Version 1.0

Practical 'Assembly Language 1'

These simple programming exercises should be attempted after the completion of chapter 3 of the courseware. You will first need to familiarise youself with the equipment in the Microprocessor Lab, and a guide to using it is included. An summary reference to the 68000 instruction set is also included, but this is not sufficient for a proper understanding of the machine. ***It is therefore essential that you have access to a reference book on 68000 Assembly Language Programming.*** One suitable book is: "68000 Family Assembly Language", A. Clements.

Programmes should start at addr. 1000H.

1. Move the contents of one 16-bit variable from address 2000H to address 2002H. Use two MOVE.W instructions. Which flags are affected? Could this operation be achieved with one instruction?

2. Add the value of location 2000H to that of location 2002H and store the result in location 2004H.

3. Determine which is the larger of two values stored at locations 2000H and 2002H. Store the larger value in address 2004H. Initially assume values are both positive. Then assume values are stored in 2's complement form; larger now means greatest magnitude.

4. Add two 64-bit values stored in locations 2000H and 2008H store the result in location 2010H.

5. Count the number of 1's in a 32-bit word held in location 2000H. Store the result in location 2004H.

6. Perform the following sequence of logical operations:

$P = A.B$	(AND)
$Q = P + B$	(OR)
$R = \underline{Q} \oplus P$	(Ex OR)
$S = R$	(NOT)

   A = 9AH, B = 0F0H.

Use break points to check intermediate values. Repeat using trace commands.

Practical 'Assembly Language 2'

These exercises should be attempted after the completion of chapter 6 of the courseware

Shift 256 8-bit data values, starting at address 2000H, to new locations starting at address 2100H.

Shift 256 8-bit values starting at address 2000H to new locations starting at address 2002H.

Write a **subroutine** which takes the 16-bit value in D0 and cubes it, leaving a 32-bit result in D0. Call this subroutine from a program which writes the cubes of the first 40 integers into consecutive locations starting at 2000H.

An Introduction to Writing and Running Programmes on the PC/MVME Systems

Note: Assembly language source files should have the suffix '.s'. The assembled 68000 object code file will automatically get the suffix '.h68', and the assembly listing file '.lis'.

Signing on to the network

You should sign on using your UCS username and password.

F:\LOGIN> login username (NON W2K)
You will now be asked for your password.

Editing a file

F:> edit filename.s

The editor is fairly self-explanatory; text is simply typed in and can be deleted when necessary using the backspace key. To save a file, press ALT-f to display the 'file' menu at the top left. Then type s for 'save'. To leave the editor, press ALT-f, then x ('exit'). A detailed help facility is available within the editor.

Assembling the source file

F:> asm filename.s

or

F:> asm -l filename.s (produces a listing of the assembled output).

Displaying the listing file

F:> type filename.lis

Connecting the PC to the MVME system

F:> soft
then two more carriage returns

MVMEBUG>
You are now connected to the MVME system; the PC is simply functioning as a front-end terminal to it. The MVMEBUG commands can now be used, including the one to download your program from the PC to the MVME system:

MVMEBUG> LO1

The MVME system is now expecting the PC to send the object code. To do so, leave the MVME system and return to the PC.

Function key 10 (F10)
Function key 6 (F6)

Description of operation	Assembler format		Operand size	Address modes src	Address modes dst	CCR bits X N Z V C
DATA TRANSFER OPERATIONS						
Move [src] to dst	MOVE	src,dst	B W L	any	da	* * 0 0
Move [src] to A-reg	MOVEA	src,An	W L	any	An	
Move 8-bit constant	MOVEQ	#data,Dn	L	#d8	Dn	* * 0 0
Move Multiple	MOVEM	regs,dst	W L	regs	ca+	
(register-list)	MOVEM	src,regs	W L	ca+	regs	
Exchange registers	EXG	Rn,Rm	L	Rn	Rm	
Extend sign-bit	EXT	Dn	W L	-	Dn	* * 0 0
Swap word 'halves'	SWAP	Dn	W	-	Dn	* * 0 0
Load 'dst' address	LEA	dst,An	L	-	c	
Push 'dst' address	PEA	dst	L	-	c	
Clear [dst] to zero	CLR	dst	B W L		da	0 1 0 0
Move SR to dst	MOVE	SR,dst	W	SR	da	
Move to/from	MOVEP	Dn,d(Am)	W L	Dn	d(Am)	
I/O registers	MOVEP	d(An),Dm	W L	d(An)	Dm	
ARITHMETIC OPERATIONS						
Add [src] ...	ADD	src,Dn	B W L	any	Dn	* * * * *
to [dst]	ADD	Dn,dst	B W L	Dn	ma	* * * * *
Add [src] to A-reg	ADDA	src,An	W L	any	An	
Add 'immediate'	ADDI	#data,dst	B W L	#d8+	da	* * * * *
Add 'quick' const.	ADDQ	#data,dst	B W L	#d3	a	* * * * *
(1..8)	ADDQ	#data,An	W L	#d3	An	* * * * *
Add [src]+X	ADDX	Dn,Dm	B W L	Dn	Dm	* * * * *
to [dst]	ADDX	-(An),-(Am)	B W L	-(An)	-(Am)	* * * * *
Subtract [src]	SUB	src,Dn	B W L	any	Dn	* * * * *
from [dst]	SUB	Dn,dst	B W L	Dn	ma	* * * * *
Subtract from An	SUBA	src,An	W L	any	An	
Subtract immediate	SUBI	#data,dst	B W L	#d8+	da	* * * * *
Subtract 'quick'	SUBQ	#data,dst	B W L	#d3	a	* * * * *
(1..8)	SUBQ	#data,An	W L	#d3	An	* * * * *
Subtract [src]+X	SUBX	Dn,Dm	B W L	Dn	Dm	* * * * *
from [dst]	SUBX	-(An),-(Am)	B W L	-(An)	-(Am)	* * * * *

Description of operation	Assembler format		Operand size	Address modes src	Address modes dst	CCR bits X N Z V C
ARITHMETIC OPERATIONS (CONTINUED)						
Negate [dst]	NEG	dst	B W L	-	da	* * * * *
Negate [dst]+X	NEGX	dst	B W L	-	da	* * * * *
Multiply signed:	MULS	src,Dn	W	d	Dn	* * 0 0
Word x Word ► Long						
Multiply unsigned:	MULU	src,Dn	W	d	Dn	* * 0 0
Word x Word ► Long						
Divide signed:	DIVS	src,Dn	W	d	Dn	* * * 0
Long - Word ► Word						
Divide unsigned:	DIVU	src,Dn	W	d	Dn	* * * 0
Long - Word ► Word						
Add BCD values	ABCD	Dn,Dm	B	Dn	Dm	* u * u *
(two digits)	ABCD	-(An),-(Am)	B	-(An)	-(Am)	* u * u *
Subtract BCD	SBCD	Dn,Dm	B	Dn	Dm	* u * u *
(two digits)	SBCD	-(An),-(Am)	B	-(An)	-(Am)	* u * u *
Negate BCD [dst]	NBCD	dst	B	-	da	* u * u *
LOGICAL OPERATIONS						
Logical AND	AND	src,Dn	B W L	d	Dn	* * 0 0
[src] with [dst]	AND	Dn,dst	B W L	Dn	ma	* * 0 0
AND 'immediate'	ANDI	#data,dst	B W L	#d8+	da	* * 0 0
Logical OR	OR	src,Dn	B W L	d	Dn	* * 0 0
[src] with [dst]	OR	Dn,dst	B W L	Dn	ma	* * 0 0
OR 'immediate'	ORI	#data,Dn	B W L	#d8+	Dn	* * 0 0
Exclusive OR	EOR	Dn,dst	B W L	Dn	da	* * 0 0
EOR 'immediate'	EORI	#data,dst	B W L	#d8+	da	* * 0 0
Logical NOT [dst]	NOT	dst	B W L	-	da	* * 0 0
'Set' one bit:	BSET	Dn,dst	B L	Dn	da	*
[src] = bit no.	BSET	#data,dst	B L	#d8	da	*
'Clear' one bit:	BCLR	Dn,dst	B L	Dn	da	*
[src] = bit no.	BCLR	#data,dst	B L	#d8	da	*
'Change' one bit:	BCHG	Dn,dst	B L	Dn	da	*
[src] = bit no.	BCHG	#data,dst	B L	#d8	da	*

Description of operation	Assembler format		Operand size	Address modes src	dst	CCR bits X N Z V C
SHIFT & ROTATE OPERATIONS (d = direction : L or R)						
Arithmetic shifts:	ASd	Dn,Dm	B W L	Dn	Dm	• • • • •
[src] = shift count	ASd	#data,Dm	B W L	#d3	Dm	• • • • •
Shift [dst] 1-bit	ASd	dst	W	-	ma	• • • • •
Logical shifts:	LSd	Dn,Dm	B W L	Dn	Dm	• • • 0 •
[src] = shift count	LSd	#data,Dm	B W L	#d3	Dm	• • • 0 •
Shift [dst] 1-bit	LSd	dst	W	-	ma	• • • 0 •
Rotate bits:	ROd	Dn,Dm	B W L	Dn	Dm	• • 0 •
[src] = bit count	ROd	#data,Dm	B W L	#d3	Dm	• • 0 •
Rotate [dst] 1-bit	ROd	dst	W	-	ma	• • 0 •
Rotate bits+X :	ROXd	Dn,Dm	B W L	Dn	Dm	• • • 0 •
[src] = bit count	ROXd	#data,Dm	B W L	#d3	Dm	• • • 0 •
Rotate [dst] 1-bit	ROXd	dst	W	-	ma	• • • 0 •
COMPARISONS & TESTS						
Compare [dst]-[src]	CMP	src,Dn	B W L	any	Dn	• • • •
" " [An]-[src]	CMPA	src,An	W L	any	An	• • • •
Compare memory	CMPM	(An)+,(Am)+	B W L	(An)+	(Am)+	• • • •
Compare [dst]-data	CMPI	#data,dst	B W L	#d8+	da	• • • •
Test: [dst]-0 ?	TST	dst	B W L	-	da	• • 0 0
Test and set [dst]	TAS	dst	B	-	da	• • 0 0
Test bit in [dst]	BTST	Dn,dst	B L	Dn	d	•
[src] = bit no.	BTST	#data,dst	B L	#d8	d	•
Set bits 1/0 on cc	Scc	dst	B	-	da	
Move [src] to CCR	MOVE	src,CCR	W	d	CCR	• • • • •
AND with CCR	ANDI	#data,CCR	B	#d8	CCR	• • • • •
OR with CCR	ORI	#data,CCR	B	#d8	CCR	• • • • •
EOR with CCR	EORI	#data,CCR	B	#d8	CCR	• • • • •

Conditions (for Scc, Bcc, DBcc)			Condition symbol			Boolean
HI	Higher	$\overline{C}\overline{Z}$	LS	Lower/Same		C+Z
CC	Carry Clear	$\overline{C}$	CS	Carry Set		C
NE	Not Equal	$\overline{Z}$	EQ	Equal		Z
VC	Overflow Clear	$\overline{V}$	VS	Overflow Set		V
PL	Plus	$\overline{N}$	MI	Minus		N
GE	Greater/Equal	$NV+\overline{N}\overline{V}$	LT	Less Than		$N\overline{V}+\overline{N}V$
GT	Greater Than	$NV\overline{Z}+\overline{N}\overline{V}\overline{Z}$	LE	Less/Equal		$Z+N\overline{V}+\overline{N}V$

Description of operation	Assembler format		Operand size	Address modes src	dst	CCR bits X N Z V C
BRANCHES, JUMPS & TRAPS						
Branch to dst	BRA	dst	B W	-	rel	
Jump to dst	JMP	dst	-	-	c	
Branch on condition	Bcc	dst	B W	-	rel	
Test cc,count to -1	DBcc	Dn,dst	W	Dn	rel	
Trap n (n = 0..15)	TRAP	#n	-	#d4	-	
Trap on overflow	TRAPV		-	-	-	
Check index bounds	CHK	src,Dn	W	d	Dn	• u u
No operation!	NOP		-	-	-	
Illegal (exception)	ILLEGAL		-	-	-	
SUBROUTINE ENTRY & EXIT						
Jump to subroutine	JSR	dst	-	-	c	
Branch to " "	BSR	dst	B W	-	rel	
Return from " "	RTS		-	-	-	
Return & reset CCR	RTR		-	-	-	• • • • •
Link stack frames	LINK	An,#data	-	An	#d16	
Unlink stack frame	UNLK	An	-	An	-	
PRIVILEGED OPERATIONS (SUPERVISOR STATE ONLY)						
Exception return	RTE		-	-	-	• • • • •
Move to status reg	MOVE	src,SR	W	d	SR	• • • • •
Move to/from	MOVE	An,USP	L	An	USP	
'User' stack ptr	MOVE	USP,An	L	USP	An	
AND with SR	ANDI	#data,SR	W	#d16	SR	• • • • •
OR with SR	ORI	#data,SR	W	#d16	SR	• • • • •
EOR with SR	EORI	#data,SR	W	#d16	SR	• • • • •
Reset (external)	RESET		-	-	-	
Stop processor!	STOP	#data	-	#d16		• • • • •

You are now back to the PC and can send the code to the MVME box with:

F:> send101 filename.h68

The code has now been sent, so to return to the MVME system:

F:> soft
then two more carriage returns

and proceed as before to use the MVMEBUG commands.

To leave the MVME system and get back to the PC:

Function key 10 (F10)
Function key 6 (F6)

To leave the PC when finished

F:> logout

Some Simple MVMEBUG Commands

Note
1. More detailed information can be found in the MVME101 reference manuals.
2. All values are assumed to be hexadecimal.

To display the contents of memory

MD <start address> <count of bytes>

To modify the contents of memory

MM <start address>

The first byte will be displayed. This may be modified. When carriage return is pressed, the new value will be stored, and the next byte will be displayed. When finished, enter '.' followed by carriage return.

To run a programme

G 1000
This assumes that the programme origin is at 1000H. If not, modify accordingly. The programme will run until it encounters the 'TRAP #15 -DC.W $10' sequence, then will terminate as described below.

MVMEBUG User I/O Subroutines

Return to MVMEBUG

```
TRAP    #15
DC.W    $10
```

Returns control to the debug monitor and prints out the register and flag contents. N.B. MUST be used at the end of a programme.

Transmit character

```
TRAP    #15
DC.W    $12
```

The ASCII character in D0 is transmitted to the serial port, and thence to the VDU.

Receive character

```
TRAP    #15
DC.W    $11
```

The keybord, via the serial port, is polled until a character is entered. This is returned in D0.

You are now back to the PC and can send the code to the MVME box with:

F:> send101 filename.h68

The code has now been sent, so to return to the MVME system:

F:> soft
then two more carriage returns

and proceed as before to use the MVMEBUG commands.

To leave the MVME system and get back to the PC:

Function key 10 (F10)
Function key 6 (F6)

To leave the PC when finished

F:> logout

Some Simple MVMEBUG Commands

Note
1. More detailed information can be found in the MVME101 reference manuals.
2. All values are assumed to be hexadecimal.

To display the contents of memory

MD <start address> <count of bytes>

To modify the contents of memory

MM <start address>

The first byte will be displayed. This may be modified. When carriage return is pressed, the new value will be stored, and the next byte will be displayed. When finished, enter '.' followed by carriage return.

To run a programme

G 1000
This assumes that the programme origin is at 1000H. If not, modify accordingly. The programme will run until it encounters the 'TRAP #15 -DC.W $10' sequence, then will terminate as described below.

MVMEBUG User I/O Subroutines

Return to MVMEBUG

```
TRAP    #15
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Returns control to the debug monitor and prints out the register and flag contents. N.B. MUST be used at the end of a programme.

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The ASCII character in D0 is transmitted to the serial port, and thence to the VDU.

Receive character

```
TRAP    #15
DC.W    $11
```

The keybord, via the serial port, is polled until a character is entered. This is returned in D0.

Description of operation	Assembler format		Operand size	Address modes src	dst	CCR bits X N Z V C
DATA TRANSFER OPERATIONS						
Move [src] to dst	MOVE	src,dst	B W L	any	da	* * 0 0
Move [src] to A-reg	MOVEA	src,An	W L	any	An	
Move 8-bit constant	MOVEQ	#data,Dn	L	#d8	Dn	* * 0 0
Move Multiple (register-list)	MOVEM	regs,dst	W L	regs	ca+	
	MOVEM	src,regs	W L	ca+	regs	
Exchange registers	EXG	Rn,Rm	L	Rn	Rm	
Extend sign-bit	EXT	Dn	W L	-	Dn	* * 0 0
Swap word 'halves'	SWAP	Dn	W	-	Dn	* * 0 0
Load 'dst' address	LEA	dst,An	L	-	c	
Push 'dst' address	PEA	dst	L	-	c	
Clear [dst] to zero	CLR	dst	B W L		da	0 1 0 0
Move SR to dst	MOVE	SR,dst	W	SR	da	
Move to/from I/O registers	MOVEP	Dn,d(Am)	W L	Dn	d(Am)	
	MOVEP	d(An),Dm	W L	d(An)	Dm	
ARITHMETIC OPERATIONS						
Add [src] ...	ADD	src,Dn	B W L	any	Dn	* * * * *
to [dst]	ADD	Dn,dst	B W L	Dn	ma	* * * * *
Add [src] to A-reg	ADDA	src,An	W L	any	An	
Add 'immediate'	ADDI	#data,dst	B W L	#d8+	da	* * * * *
Add 'quick' const. (1..8)	ADDQ	#data,dst	B W L	#d3	a	* * * * *
	ADDQ	#data,An	W L	#d3	An	* * * * *
Add [src]+X to [dst]	ADDX	Dn,Dm	B W L	Dn	Dm	* * * * *
	ADDX	-(An),-(Am)	B W L	-(An)	-(Am)	* * * * *
Subtract [src] from [dst]	SUB	src,Dn	B W L	any	Dn	* * * * *
	SUB	Dn,dst	B W L	Dn	ma	* * * * *
Subtract from An	SUBA	src,An	W L	any	An	
Subtract immediate	SUBI	#data,dst	B W L	#d8+	da	* * * * *
Subtract 'quick' (1..8)	SUBQ	#data,dst	B W L	#d3	a	* * * * *
	SUBQ	#data,An	W L	#d3	An	* * * * *
Subtract [src]+X from [dst]	SUBX	Dn,Dm	B W L	Dn	Dm	* * * * *
	SUBX	-(An),-(Am)	B W L	-(An)	-(An)	* * * * *

Description of operation	Assembler format		Operand size	Address modes src	dst	CCR bits X N Z V C
ARITHMETIC OPERATIONS (CONTINUED)						
Negate [dst]	NEG	dst	B W L	-	da	* * * * *
Negate [dst]+X	NEGX	dst	B W L	-	da	* * * * *
Multiply signed: Word x Word ▸ Long	MULS	src,Dn	W	d	Dn	* * 0 0
Multiply unsigned: Word x Word ▸ Long	MULU	src,Dn	W	d	Dn	* * 0 0
Divide signed: Long - Word ▸ Word	DIVS	src,Dn	W	d	Dn	* * * 0
Divide unsigned: Long - Word ▸ Word	DIVU	src,Dn	W	d	Dn	* * * 0
Add BCD values (two digits)	ABCD	Dn,Dm	B	Dn	Dm	* u * u *
	ABCD	-(An),-(Am)	B	-(An)	-(Am)	* u * u *
Subtract BCD (two digits)	SBCD	Dn,Dm	B	Dn	Dm	* u * u *
	SBCD	-(An),-(Am)	B	-(An)	-(Am)	* u * u *
Negate BCD [dst]	NBCD	dst	B	-	da	* u * u *
LOGICAL OPERATIONS						
Logical AND [src] with [dst]	AND	src,Dn	B W L	d	Dn	* * 0 0
	AND	Dn,dst	B W L	Dn	ma	* * 0 0
AND 'immediate'	ANDI	#data,dst	B W L	#d8+	da	* * 0 0
Logical OR [src] with [dst]	OR	src,Dn	B W L	d	Dn	* * 0 0
	OR	Dn,dst	B W L	Dn	ma	* * 0 0
OR 'immediate'	ORI	#data,Dn	B W L	#d8+	Dn	* * 0 0
Exclusive OR	EOR	Dn,dst	B W L	Dn	da	* * 0 0
EOR 'immediate'	EORI	#data,dst	B W L	#d8+	da	* * 0 0
Logical NOT [dst]	NOT	dst	B W L	-	da	* * 0 0
'Set' one bit: [src] = bit no.	BSET	Dn,dst	B L	Dn	da	*
	BSET	#data,dst	B L	#d8	da	*
'Clear' one bit: [src] = bit no.	BCLR	Dn,dst	B L	Dn	da	*
	BCLR	#data,dst	B L	#d8	da	*
'Change' one bit: [src] = bit no.	BCHG	Dn,dst	B L	Dn	da	*
	BCHG	#data,dst	B L	#d8	da	*

Description of operation	Assembler format	Operand size	Address modes src	dst	CCR bits X N Z V C
SHIFT & ROTATE OPERATIONS (d = direction : L or R)					
Arithmetic shifts:	ASd Dn,Dm	B W L	Dn	Dm	• • • • •
[src] = shift count	ASd #data,Dm	B W L	#d3	Dm	• • • • •
Shift [dst] 1-bit	ASd dst	W	-	ma	• • • • •
Logical shifts:	LSd Dn,Dm	B W L	Dn	Dm	• • • 0 •
[src] = shift count	LSd #data,Dm	B W L	#d3	Dm	• • • 0 •
Shift [dst] 1-bit	LSd dst	W	-	ma	• • • 0 •
Rotate bits:	ROd Dn,Dm	B W L	Dn	Dm	• • 0 •
[src] = bit count	ROd #data,Dm	B W L	#d3	Dm	• • 0 •
Rotate [dst] 1-bit	ROd dst	W	-	ma	• • 0 •
Rotate bits+X :	ROXd Dn,Dm	B W L	Dn	Dm	• • • 0 •
[src] = bit count	ROXd #data,Dm	B W L	#d3	Dm	• • • 0 •
Rotate [dst] 1-bit	ROXd dst	W	-	ma	• • • 0 •
COMPARISONS & TESTS					
Compare [dst]-[src]	CMP src,Dn	B W L	any	Dn	• • • •
" " [An]-[src]	CMPA src,An	W L	any	An	• • • •
Compare memory	CMPM (An)+,(Am)+	B W L	(An)+	(Am)+	• • • •
Compare [dst]-data	CMPI #data,dst	B W L	#d8+	da	• • • •
Test: [dst]-0 ?	TST dst	B W L	-	da	• • 0 0
Test and set [dst]	TAS dst	B	-	da	• • 0 0
Test bit in [dst]	BTST Dn,dst	B L	Dn	d	•
[src] = bit no.	BTST #data,dst	B L	#d8	d	•
Set bits 1/0 on cc	Scc dst	B	-	da	
Move [src] to CCR	MOVE src,CCR	W	d	CCR	• • • • •
AND with CCR	ANDI #data,CCR	B	#d8	CCR	• • • • •
OR with CCR	ORI #data,CCR	B	#d8	CCR	• • • • •
EOR with CCR	EORI #data,CCR	B	#d8	CCR	• • • • •

Conditions (for Scc, Bcc, DBcc)		Condition symbol	Boolean
HI Higher	$\bar{C}\bar{Z}$	LS Lower/Same	$C+Z$
CC Carry Clear	$\bar{C}$	CS Carry Set	C
NE Not Equal	$\bar{Z}$	EQ Equal	Z
VC Overflow Clear	$\bar{V}$	VS Overflow Set	V
PL Plus	$\bar{N}$	MI Minus	N
GE Greater/Equal	$NV+\bar{N}\bar{V}$	LT Less Than	$N\bar{V}+\bar{N}V$
GT Greater Than	$NV\bar{Z}+\bar{N}\bar{V}\bar{Z}$	LE Less/Equal	$Z+N\bar{V}+\bar{N}V$

Description of operation	Assembler format	Operand size	Address modes src	dst	CCR bits X N Z V C
BRANCHES, JUMPS & TRAPS					
Branch to dst	BRA dst	B W	-	rel	
Jump to dst	JMP dst	-	-	c	
Branch on condition	Bcc dst	B W	-	rel	
Test cc,count to -1	DBcc Dn,dst	W	Dn	rel	
Trap n (n = 0..15)	TRAP #n	-	#d4	-	
Trap on overflow	TRAPV	-	-	-	
Check index bounds	CHK src,Dn	W	d	Dn	• u u
No operation!	NOP	-	-	-	
Illegal (exception)	ILLEGAL	-	-	-	
SUBROUTINE ENTRY & EXIT					
Jump to subroutine	JSR dst	-	-	c	
Branch to " "	BSR dst	B W	-	rel	
Return from " "	RTS	-	-	-	
Return & reset CCR	RTR	-	-	-	• • • • •
Link stack frames	LINK An,#data	-	An	#d16	
Unlink stack frame	UNLK An	-	An	-	
PRIVILEGED OPERATIONS (SUPERVISOR STATE ONLY)					
Exception return	RTE	-	-	-	• • • • •
Move to status reg	MOVE src,SR	W	d	SR	• • • • •
Move to/from	MOVE An,USP	L	An	USP	
'User' stack ptr	MOVE USP,An	L	USP	An	
AND with SR	ANDI #data,SR	W	#d16	SR	• • • • •
OR with SR	ORI #data,SR	W	#d16	SR	• • • • •
EOR with SR	EORI #data,SR	W	#d16	SR	• • • • •
Reset (external)	RESET	-	-	-	
Stop processor!	STOP #data	-	#d16		• • • • •

Appendix F

COGNITIVE STYLES ANALYSIS INTERPRETATION SHEET

Your Results

Enter you results from the final display screen.

COGNITIVE STYLE .... - ....

Wholist-Analytic Ratio =

Verbal-Imagery Ratio =

Cognitive Style Descriptions

An individual's cognitive style affects the manner in which information is processed during learning and thinking. It also influences the manner in which they respond to other people and social situations. Individuals vary in style from one extreme to the other.

A cognitive style is different from intelligence in that an individual at one end of the continuum will be good at some tasks and poor at others, while for a person at the other extreme the situation will be the reverse.

The two fundamental dimensions of cognitive style assessed are the Wholist-Analytic mode of processing information and the Verbal-Imagery style of the representation of information during thinking.

These two styles are independent of one another, that is the position of an individual on one dimension of cognitive style does not affect their position on the other. For instance a person may be a Wholist and an Imager, and another an Analytic and an Imager, or another may be a Wholist and a Verbaliser, while someone else may be Analytic and a Verbaliser.

WHOLIST-ANALYTIC COGNITIVE STYLE

Description

When they consider information, Wholists will have a balanced view of the whole, while Analytics will separate it out into its parts, or sections.

Effect on Learning Performance

WHOLIST	ANALYTIC
IS ABLE TO SEE THE WHOLE	ANALYSES MATERIAL INTO ITS PARTS
FINDS DIFFICULTY IN DISEMBEDDING	FINDS DIFFICULTY IN SEEING THE WHOLE

The positive strength of the Wholists is that they see the whole 'picture', the negative that they find difficulty in separating out parts. Socially they see a social group as a whole.

For Analytics, their positive ability is that they can analyse information into the parts, but may not be able to get a balanced view of the whole. Socially, they will tend to view a social group as a collection of individuals.

VERBAL-IMAGERY COGNITIVE STYLE

Description

Basically, when people who are Imagers read, listen to, or consider information they experience fluent, spontaneous and frequent mental pictures. By contrast, individuals who are Verbalisers read, listen to, or consider, information in words. The Verbal-Imagery mode of representation is a continuum with individuals placed along it. People in the middle tend to use either mode of representation.

Effect on Learning Performance

VERBALISER	IMAGER
LEARNS BEST FROM VERBAL PRESENTATION	LEARNS BEST FROM VISUAL DISPLAYS
FINDS SPEECH AND TEXT EASIER THAN DIAGRAMS	FINDS PICTURES EASIER THAN WORDS

It also has to do with the location of their representation - verbal has to do primarily with social communication since it is the basic medium of communicating with others, while imagery has to do with a world internal to the individual, which may be constructed with mental pictures. Consequently, it has important social implications as well as learning ones.

Appendix G

Number Systems Module Quiz

Case Study Two, 8th February 2002

Student Number:

IMPORTANT INSTRUCTIONS
The following multiple-choice questions are intended to help us gain an insight into your knowledge of Number Systems. Please select one answer only to each question. **All information provided will be held in strictest confidence and will not have any bearing on your formal assessment for this part of the course.**

Please circle one letter (A, B, C or D) only, in answer to each question.

1. **In the decimal number 5864, the 5 is multiplied by...**

   A. 10^0

   B. 10^3

   C. 10^1

   D. don't know

2. **Which base number is used in the binary number system?**

   A. 4

   B. 6

   C. 2

   D. don't know

3. **Each digit in a binary number is multiplied by a power of...**

A. 1

B. 2

C. 4

D. don't know

4. **The decimal equivalent of the binary number 1101 is...**

A. 12

B. 9

C. 13

D. don't know

5. **Which base number is used in the hexadecimal number system?**

A. 4

B. 16

C. 8

D. don't know

6. **The decimal equivalent of the hexadecimal number 2E is...**

A. 46

B. 752

C. 192

D. don't know

7. How many binary digits does a hexadecimal digit correspond to?

A. 3

B. 2

C. 4

D. don’t know

8. The 10's complement of the decimal number 349 is...

A. 650

B. 651

C. 761

D. don’t know

9. Subtraction (a - b) in a practical computer is done by...

A. negating b and adding it to a

B. complementing b and subtracting it from a

C. complementing b and adding it to a

D. don't know

10. The sum of the hexadecimal values 23 and 18 is...

A. 41

B. 3B

C. 2X

D. don't know

End

Appendix H

Introduction to Computer Systems Quiz

Case Study Two, 15th February 2002

Student Number:

IMPORTANT INSTRUCTIONS

The following multiple-choice questions are intended to help us gain an insight into your knowledge of computer systems.

Please select one answer only to each question.

All information provided will be held in strictest confidence and will not have any bearing on your formal assessment for this part of the course.

Please circle one letter (A, B, C or D) only, in answer to each question.

1. **Which part of a computer system carries out arithmetic calculations?**

   A. Input-Output unit

   B. Memory unit

   C. Arithmetic-logic unit

   D. Don't know

2. **Which of the following best describes the use of a 16-bit word of data in a computer system?**

   A. It may represent one of 2^{16} possible items of data or one of 2^{16} possible instructions.

   B. It always represents one of 2^{16} possible items of data.

   C. It represents one of 2^{8} possible items of data, together with one of 2^{8} possible instructions.

   D. Don't know

3. **What function does the Highway (or Bus) carry out in a computer system?**

A. Converts data from high-level to low-level language.

B. Transfers data from one part to another.

C. Allows data to enter or leave the computer from the Internet.

D. Don't know

4. **RAM stands for...**

A. Read Access Memory

B. Read Arithmetic Memory

C. Random Access Memory

D. don't know

5. **A ROM is a memory device which can be ...**

A. Read from, but not written to during normal service

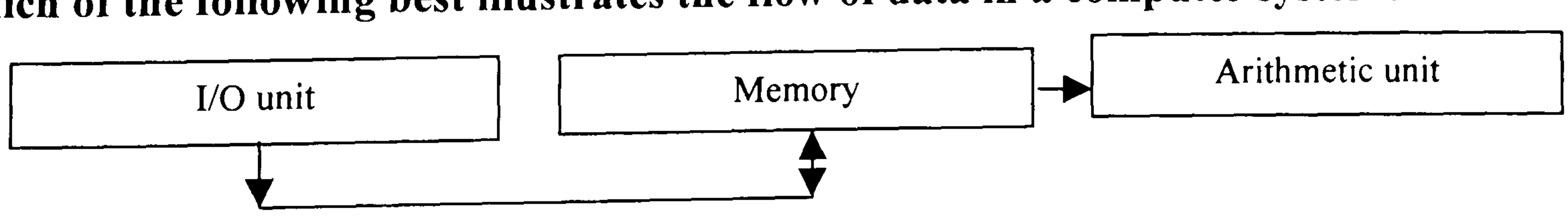
B. Read from and written to at any time

C. Written to freely, but must be read back in a fixed sequence

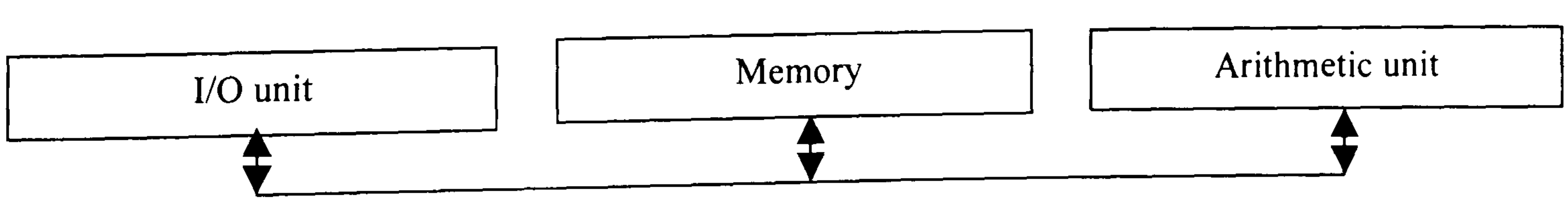
D. Don't know

6. **Which of the following best illustrates the flow of data in a computer system?**

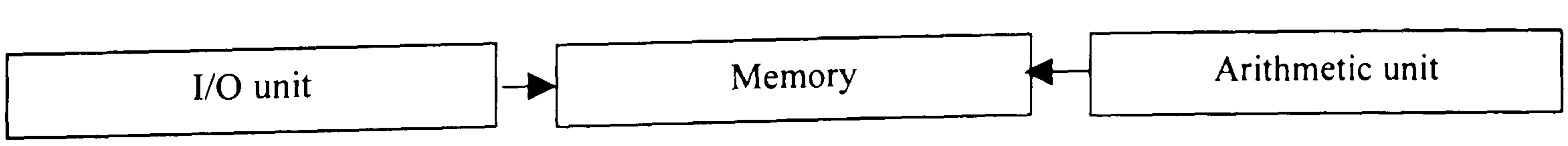
A.



B.



C.



D. Don't know

7. **Which of the following diagrams illustrates the most appropriate layout for an instruction on a 16-bit computer system?**

A.

12 Bits - Operation	**4 Bits** – Location in store

B.

4 Bits - Operation	**12 Bits** – Location in store

C.

16 Bits - Operation	**8 Bits** – Location in store

D. Don't know

8. **Which statement best describes the function of 'operation code' or 'opcode'?**

A. It generates computer instructions.

B. It starts a program.

C. It tells the computer what to do.

D. Don't know

9. **Which statement best describes the function of the 'Control Unit' ?**

A. It controls the movement of information around the computer.

B. It controls the number of bits which are being used in a computer.

C. It transfers data from ROM to RAM memory.

D. Don't know

10. **Which diagram best illustrates the 'fetch – execute' cycle of an instruction which loads the accumulator from memory?**

A. Instruction from Input Unit to Control Unit → Control Unit takes opcode and tells Memory to read data onto Highway → Control Unit tells Accumulator to load data from Highway

B. Instruction from Memory to Control Unit → Control Unit takes opcode and tells Memory to read data onto Highway → Control Unit tells Accumulator to load data from Highway

C. Instruction from Memory to Control Unit → Control Unit takes opcode and tells Input Unit to read data onto Highway → Control Unit tells Accumulator to read data onto Highway

D. Don't know

End

Appendix I

Observation/Student Interview Notes – Case Study 2

8th February 2002

Number Systems Module – 3hrs duration
Working Sample Size – 50 students approx.

Pre-test Notes

- Noted a small minority of students using calculators

Lecturer's introduction to EDEC module

- Student note taking strongly encouraged.
- No workbook used to accompany module.
- Students encouraged to take their time in working through module.
- Lecturer and two demonstrators available to take student questions during session.

Observations

- A number of students observed taking written notes whilst animated elements were running.
- A general lack of note taking was observed at the start of the session.
- Students observed taking notes around 20 minutes into session. Most of these tended to be non-structured.
- Evidence of 'play Vs learning' was observed with students trying out interactive elements prior to learning.
- Some students used 'skimming' to review the interface and material in a superficial manner before learning took place.
- The great majority of students worked through the package on an individual basis with little group consultation observed.
- There was some evidence of confusion as to which elements were interactive and which were not (e.g. underlined blue text – recognised as an Internet link).
- Some students having difficulty with longer, more complex animated examples (e.g. calculations).
- Students starting to complete module after around 1 hour.
- All students completed module within 1hr 30mins.

Student Questions

- Almost all students questioned indicated that the general pace of each animation was about right.
- Almost all students questioned indicated that they were having no difficulty in processing the information on screen.
- Most students questioned expressed a preference for computer based learning materials over books/lectures.
- One student highlighted the reverse logic of the input window for a binary calculation.
- Some students expressed a need for more control of animated elements.

Developer Questions

- Basis for frame speed of animated elements was expressed as being 'intuitive'.

Observation/Student Questions – Notes

15th February 2002

Introduction to Computer Systems Module – 3hrs duration

Working Sample Size – 50 students approx.

Pre-test Notes

- No problems encountered during administration of pre-test.

Lecturer's introduction to EDEC module

- EDEC workbook for module distributed to all students.
- Students encouraged to take their time in working through module.
- Lecturer and two demonstrators available to take student questions during session.
- Access to EDEC modules is available to all students off-campus via a network log-in.

Observations

- Vast improvement in degree of note taking observed with the accompaniment of the EDEC notebook.
- Most animated sequences being reviewed once only.
- Animations observed to be stimulating note taking via workbooks.
- Observed a number of students initiating animation and doing something else until the animation was complete or note taking whilst animation proceeded (some students seemed only to be interested in the final screen).
- Some students (approx. 10%) observed to have completed module after 20mins. of 3 hours allocated for session.
- Some evidence of 'pairing off' of students, although most students still working on an individual basis.
- Very different learning environment observed in the upstairs (smaller) computer lab, where work through the module was more group orientated (these students were all Greek).
- The great majority (approx. 90%) of student observed to have completed module by 1 hour mark.

Student Questions

- Most students expressed no concern as to the speed or complexity of animated elements.
- Many students said that a single review of animated elements was enough to process the information within.
- Most students questioned responded to the workbooks in generally positive terms.
- Some expressed a wish for the workbooks to be more informative, like the module screens.

- Many students said that there was insufficient space within the workbooks for note taking.
- Some students expressing a definite preference for this type of material (EDEC). Flexibility and self-study opportunities cited alongside an element of fun.
- One student said that the animated elements had no bearing on his ability to learn or the quality of his learning experience.
- One student expressed concern about the amount of processing required for some of the more complex animated screens. He did feel that the animations however provided a useful platform for indicating the tranfer of information in a computer.
- A number of students said that the animations were a little too fast.
- One student who identified herself as a 'slow reader' expressed concern over the speed of animations and the links between the module content and the EDEC workbook.
- One student expressed a real preference for the EDEC approach, saying he..."wished he'd had it for C++." He did say however that he found some of the animations too fast , although useful.

Observation/Student Questions – Notes

22nd February 2002

Introduction to Assembly Language Module – 3hrs duration
Working Sample Size – 50 students approx.

CSA Test Notes

- Possible language issues/problems with foreign students highlighted.
- No problems encountered in administration of test.

Lecturer's introduction to EDEC module/lecture

- A general lack of responses to lecturer questions on last weeks module observed. There was a real sense of a 'lack of understanding' apparent. There was some degree of surface learning evident, particularly where information processing was required.
- Responses to lecturer questions may be due to the absence of a tutorial workbook for previous module (one was given out at end of Number Systems module).
- Observed definite anecdotal links between processing of animated elements and retention of information under lecturer questioning of students. This may be linked to animation timing and the fact that students generally only review animations once.
- On review of last week's results for pre/post test, question 2 was identified as having caused biggest problem for students. It was noted that this particular question required extrapolation from the EDEC module, whilst other questions directly tested material within the module.
- A high degree of discomfort/peer pressure was observed when students were asked to answer question 2 during lecture. Most students however selected the correct answer.
- Lack of responses to lecturer questions may be linked to observed tendency for many students to 'skim' previous modules during sessions.

Observations

- Observed a reluctance to enter the EDEC module this week. Many students chatting, checking e-mail, surfing Web at start of session.
- Some students choosing not to use the workbook provided and preferring to take their own notes instead.
- Very obvious incidence of student starting animation and chatting to friend until the animation had finished. When asked immediately afterwards the student said that he really liked the animations as they really helped to "break down" the problem. This was despite the fact that he hadn't actually observed the animation.
- Two students observed skimming past animations (C1/S1/P8) without effective review of information within.
- Students generally observed to be interested and making reference to notes to answer interactive questions within the module.
- Some students observed to be working between EDEC module and e-mail etc. throughout the session.
- First students (approx. 10%) observed to have finished module after 25mins.
- Workbooks observed to be well utilised in general to support computer activity.
- A number of students observed having difficulty or confused by interactive/non-interactive content. This was largely identified as coloured text (red and blue) which appeared to be seen as hyperlinks.
- In a number of cases students were observed to be merely hunting for interactive elements within modules as they progressed.
- Students tending to work through the module in isolation as per weeks 1 and 2.
- Around 50% of students finished module after 40mins.
- Once students started to leaved it gained momentum very quickly.
- A disparity of finish time was observed between the downstairs (main lab) at around 45mins for the majority of students and upstairs (small lab). This follows a 3 week pattern.
- Again, more observable group activity upstairs (Greek students).

Observation/Student Questions – Notes

1st March 2002

Introduction to Assembly Language Lab Session 1
3hrs duration (10am – 1pm)
Working Sample Size – 50 students approx.

Lecturer's introduction to lab session

- Distribution of 'Practicals' workbook for session.
- Session starts late due to late arrival of many students (approx. 50%).
- Students asked to work in groups of 2.

Observations

10.10am

- Immediately observed different group dynamic with groups cooperating with each other and other groups almost immediately.
- Lecturer's approach is to have all students moving together for first hour of session, which is directed by his prompting.

10.20am

- First question from workbook introduced by lecturer.
- Vast majority of students observed not to be using notes from previous EDEC sessions (around 6 out of 45).

10.25am

- Approx. 50% of students either have own notes, EDEC workbooks or course book by their sides, although few are referring to any of them.

10.30am

- Students asked to run program written by lecturer. Many students receive an 'error' message, which has been anticipated by the lecturer. This leads to lecturer leading students through the process for this step.
- Almost no observable use of EDEC workbooks at this stage.
- Much greater degree of cooperation observable when compared to EDEC sessions.

10.35am

- Noted that student motivation has generally been high during this lab session.
- Observed a high degree of demonstrator support being given during session (2 demonstrators present).

10.40am

- Observed use of notes:
    - Own notes – 1 to 2 students
    - EDEC notes – 1 student
    - Course book – 0 students
- Three or four students observed to be taking notes as they proceed.
- Around 50% of students not responding to instructions from lecturer.

10.45am

- One student expressed a need for more notes for the practical sessions as he "couldn't remember" the content of the EDEC sessions. He also questioned the relevance of the EDEC modules to the practical lab.
- No use of EDEC notes at this stage. Almost complete reliance on 'Practicals' workbook.

10.50am

- On explicit instructions from lecturer, almost no students observed to be taking notes.
- At this stage most student activity is being directed by the lecturer.

10.55am

- Observed first real signs of a small number of students losing interest and talking to friends, wandering, reading newspaper.
- Some students observed to be working ahead of lecturer instructions in an effective manner.
- Approx. 50% of students requiring direct prompting from lecturer.
- Most students proceeding effectively, either independently or with lecturer prompts.

11.00am

- When lecturer asked a question which was explicitly linked to previous week's EDEC module (conditional path), most students observed to be unsure or did not know the answer.
- Some evidence of EDEC workbooks being referred to at this stage.

11.05am

- Large number of students now observed to be working within groups and independent of lecturer prompting.

11.10am

- Question 1 from 'Practicals' workbook completed by lecturer.
- Students move onto questions 2 and 3 and expected to work without lecturer prompts at this stage.

11.20am

- Two students with some experience of JAVA/C++ said that whilst the EDEC modules were not strictly necessary for them (due to prior knowledge), it did prepare them for some terms such as 'flags', which was useful during the lab.
- All students now seem motivated to work at own pace through the lab.
- Lots of communication is evident amongst and between student pairs.
- One student said that the EDEC modules had prepared him for the lab, although he felt that he should have taken more notes during the EDEC sessions.
- Three students with no previous programming experience felt that the EDEC material prepared them for the lab.
- One student said she preferred to work from her own notes now because the EDEC workbooks... "Didn't have enough space for note taking." She was however observed to be referring to EDEC notes during lab.

11.30am

- Some signs of students giving up.
- Demonstrator indicates that a much greater level of support is required for the lab sessions over the EDEC sessions.

11.35am

- Four students said that whilst the EDEC modules provided some useful general support in understanding the topic, the material didn't specifically support the lab session.
- They said that they were largely relying on their previous experience in using C+/C++ etc.

- They said that an additional module which provided greater detail on programming specifically related to the Motorola 68000 chip would have been useful.
- ** This has implications for the strategy and degree of integration of EDEC modules into the context of wider learning aims.
- **Also highlights the issue of module and media granularity.

11.40am

- Almost no observable reference to any notes apart from 'Practicals' workbook at this stage.

11.45am

- Two students said that the EDEC modules provided little preparation for the lab, although it did offer some prompts.
- They said that this was true of the EDEC workbooks as well.
- Lots of students observed to be requiring support from lecturer/demonstrators.
- Lots of inter-group cooperation apparent. This is in contrast to the individual approach which was observed during all EDEC sessions.
- Motivation high to answer questions within the 'Practicals' workbook and complete the lab.
- Some students appear to be giving up at this stage.
- One student said that although the EDEC modules only helped to an extent, he still preferred the EDEC format to the traditional lecture format.

11.55am

- Two students said that whilst the first two EDEC modules were useful in giving a broad overview of the topic in support of the lab, the 3rd module provided less support as the information within was too complex to take in.
- Both students expressed concern at the amount of information processing required for the 3rd module and how little preparation it provided for the lab.
- Both students had dropped the EDEC workbooks in favour of their own notes due to the lack of space for note taking within the workbooks.
- Both students said that the lab would have benefitted from a traditional lecture or additional notes, prior to beginning.
- One student of the two expressed a particular dislike for learning through a computer.

12.05pm

- **Note taken to ask lecturer the pedagogical philosophy behind the integration of the EDEC modules with the lab sessions. Lecturer said that the EDEC modules were never intended to fully integrate with the lab sessions.

12.10pm

- Some student showing signs of finishing/giving up.

12.25pm

- Observed some students starting to support others around the room.
- No real note taking observed throughout the session.

- In general, observed good cooperation between students in pairs with few instances of observable domination within groups.

12.30pm

- Approx. 50-60% of students observed to have finished/given up.

12.40pm

- Demonstrator agreed that questions being asked of him indicated a lack of translation of information or relationship between EDEC modules and lab session.
- Majority of students still present, although many are not working through lab.

Observation/Student Questions – Notes

8th March 2002

Introduction to Assembly Language Lab Session 2
3hrs duration (10am – 1pm)
Working Sample Size – 42 students approx.

Observations

10.05am

- Students observed to be starting session without the need for prompting from lecturer.

10.10am

- Lecturer reviews question 4 from workbook with students.

10.15am

- Students generally show reluctance/confusion in responding to lecturer questions on question 4.
- Observed an almost complete lack of response to questions which relate to process activity.
- **Is this due to students' ability to translate theory to practical lab sessions or identifying EDEC material covered as being discrete from practical lab knowledge requirements?
- Lack of responses to questioning prompts lecturer to point out that he may be 'going too fast.'

10.25am

- Some evidence of student disinterest/demotivation when theory behind question 4 is reviewed by lecturer.
- Very obvious confusion evident among students regarding theory. Some student observed to be losing interest.

10.30am

- Students paying close attention to lecturer input regarding 'flags' covered during EDEC sessions.

10.35am

- Around 50% of students take part in lecturer's review of theory.
- Observed no or very few notes being taking during lecturer review/instructions.

10.40am

- Observed that many of the students who have given up on the lecturer's review are those who are progressing more slowly.

10.45am

- Ask 2 students if EDEC material provides their only support prior to the practical labs. Response: "Yeah, unfortunately."

10.50am

- Asked 3 students about the links between learning through EDEC and lab sessions. They all thought that whilst the EDEC material provided a good overview of the underlying theory, it provided no real preparation for the labs themselves.
- They said that their approach to the practical labs was 'trial and error'.
- Discussion with student who had missed the previous lab (1st). Suggested that he joined up with another student. His response: "Nobody seems to know what they're doing."

10.55am

- Lots of student cooperation evident.
- Lots of support required from lecturer/demonstrators.
- 1 student recognised in discussion that the lab session required more actual programming practice than delivery of theory through lectures.

11.00am

- Some students observed to be forming larger groups to do the work.

11.05am

- Two students who are making good progress and are in advance of the class generally indicate their primary resource for labs as being the 'instructions' within the workbook. One student said that the course book "...didn't help that much." Both students agreed that the EDEC sessions were of no use to their learning at this point. They also indicated the need for either another module of lecture(s) to link the EDEC modules covered and the lab sessions.
- **Note that the lecturer indicated later, a reluctance to include 'instructions' within the workbook' as they only provided a subset of those covered by the course book.

11.15am

- Two students both agreed they were not confident in carrying out their present task and were simply using 'trial and error' in completion of the questions within the workbook.
- They thought that their learning would have benefitted from either and additional EDEC module or lecture(s). They felt comfortable with the theory covered by the EDEC modules, although they expressed difficulty in applying this knowledge in the practical sessions.

11.30am

- Most students still working through tasks, although first evidence of some students losing interest.

11.40am

- Signs of students having given up or lost interest are much more observable this week than last.

11.45am

- Two students who are progressing well indicated the need the need for some module/lecture support for the link between 'instructions' in workbook and program compilation. They indicated that they were utilising 'programming logic' from prior learning.
- Observed a large degree of support required from lecturer/demonstrators. Waiting is having an effect on demoralising students.

11.50am

- Around 20% of students have progressed to question 5 in the workbook.
- Lecturer introduces this question to students through a 'mini lecture'.

12.00am

- When asked, students unaware of how this learning will be assessed (programming assignment).
- Lots of interest in 'mini lecture', particularly from slower students who have not yet reached question 5.
- Demonstrator said that support was easier this week due to the learning which took place last week. Students had gained an understanding of the programming structure and therefore require more prompts/fault-finding than actual lead through on questions.

12.10pm

- Students generally becoming more restless and some students starting to leave lab.

12.15pm

- Administer questionnaire.

Observation/Student Questions – Notes

15th March 2002

Introduction to Assembly Language Lab Session 3
3hrs duration (10am – 1pm)
Working Sample Size – 38 students approx.

10.15am

- Introduction to session by lecturer.

10.20am

- Students observed to be working generally in the same pairings as previous weeks and in similar room placings.
- Students asked by lecturer to input a program to computer and wait for further instructions. This was observed to have been carried out effectively by most pairings.
- Students asked to take notes on new 'instruction' as it wasn't within workbook.

- When asked if students had a 'display of registers' after instructions, no students identified problems.

10.25am

- Students generally seem comfortable with the task at this stage.
- Observed a more comfortable atmosphere as students are now acquainted with type of task and lab environment.

10.30am

- Although many students have course notes available, most are relying purely on 'Practicals' workbook.

10.35am

- Observed a continuation of student support evident amongst groups. Students obtaining support from friends as well as demonstrators as required.

10.40am

- Vast majority of students observed to be motivated by task.
- No reliance on EDEC notes evident (as expected).
- Note from lecturer on students who claim to be finished – "still a little soft round the edges."

10.45am

- Students working and supporting each other to an extent independent of the lecturer/demonstrators as evidence of confidence.

10.50am

- Lecturer questioning of two students on question 5 from the workbook, highlighting procedural errors in students model program. Lecturer asking questions of student to assess knowledge and prior knowledge (e.g. C++).
- There may be evidence of wrongful application of prior learning (e.g. C++) here as programming structures and principles are not the same.
- This is further evidenced where lecturer is required to give extensive instructions to tow students in terms of best practice and correction of students application of knowledge of programming.
- Definite observed link of benefits of face to face interaction and student problem solving/progress.
- Good observable discussion of problem and co-operative learning within the lab environment.
- Very business-like environment throughout. Less observable motivation problems observed, although this is the last session.

11.05am

- Noted that student interaction with demonstrators is now more focused and defined, giving evidence of learning taking place.
- **Note:** This was confirmed through subsequent discussion with demonstrator.

11.10am

- Far fewer observable signs of students not knowing what they are doing.

- Some evidence of own note taking to supplement workbook.

11.15am

- Generally noted a high degree of detail in support/discussion from lecturer in assessing students' knowledge.

11.20am

- Student who was observed reading a newspaper for previous 15 mins. was in fact waiting for assistance. The lack of demonstrators to offer support has a demotivating affect on some students.

11.25am

- Students still largely motivated by task.

11.30am

- Lecturer seems happy with the knowledge and understanding of students upon questioning of two students regarding to structure of task.
- Lecturer covers question 6 from workbook on the board. Around 60% of students gathered for this mini lecture. Students appear significantly more confident in terms of body language and responses to lecturer at the end of the mini lecture.

11.40am

- Question 5 generally being used by lecturer as an assessment benchmark. This is confirmed by the lecturer as a precursor to the assignment.

12.00pm

- First signs of students preparing to leave or actually leaving.
- Distribute confidence log.

12.10pm

- Around 50% of students left in lab.
- All students seem confident in their ability to carry out the assignment as it raises few questions with the lecturer.

12.20pm

- Those students still present (50%), generally still motivated by the task. As preparation for the assignment.

12.25pm

- Students who lack motivation observed to have a tendency to cluster. Two particular students show reluctance to participate in the evaluation, although they did complete the questionnaire.
- Direct link between student frustration and support available observed.

12.30pm

- Little or no observable student frustration with the task now. Obvious change in class confidence since week one linked to their insecurity.

12.35pm

- Approx. 25% of students still working in lab.
- Generally much higher degree of group problem solving today.
- Student confidence and knowledge of programming structures clearly evident.

- **Note:** This shows real evidence of the relevance and importance of experiential learning.
- **Note:** Practical labs tending more towards a deep approach to learning over the EDEC sessions.

Appendix J

EDEC Digital Design Theme
Introduction to Computer Systems

Workbook

Date – 14 November 1997
Author – David Brittle

1) Aims of Module

On completing this module you will know:

- what a computer does
- the main elements of a computer
- what computer instructions are
- how these instructions are carried out

2) Module Prerequisites

Knowledge of binary representation.

3)Tools and Equipment

None.

4) The Workbook

This is a workbook for you to log results and notes in whilst you progress through the course material. This book will also act as a source of reference in the future.

Chapter 1 Introduction

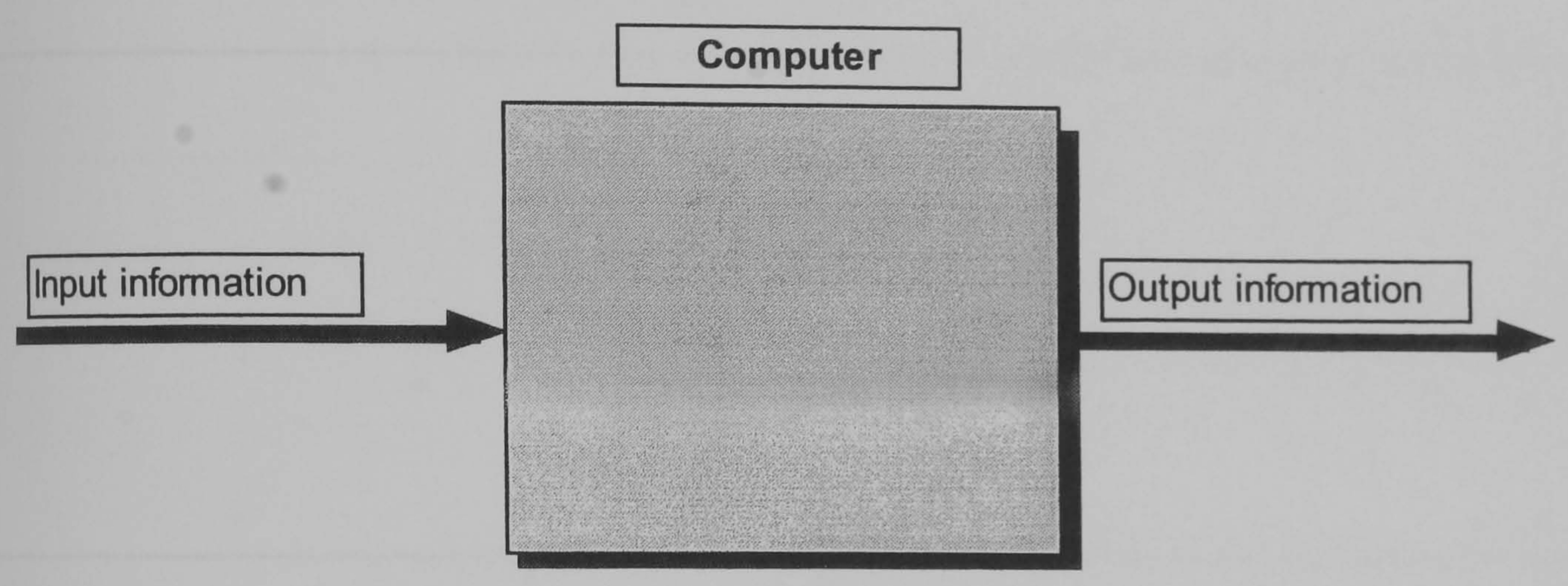
No notes

Chapter 2 What does a computer do?

Section 1

No notes

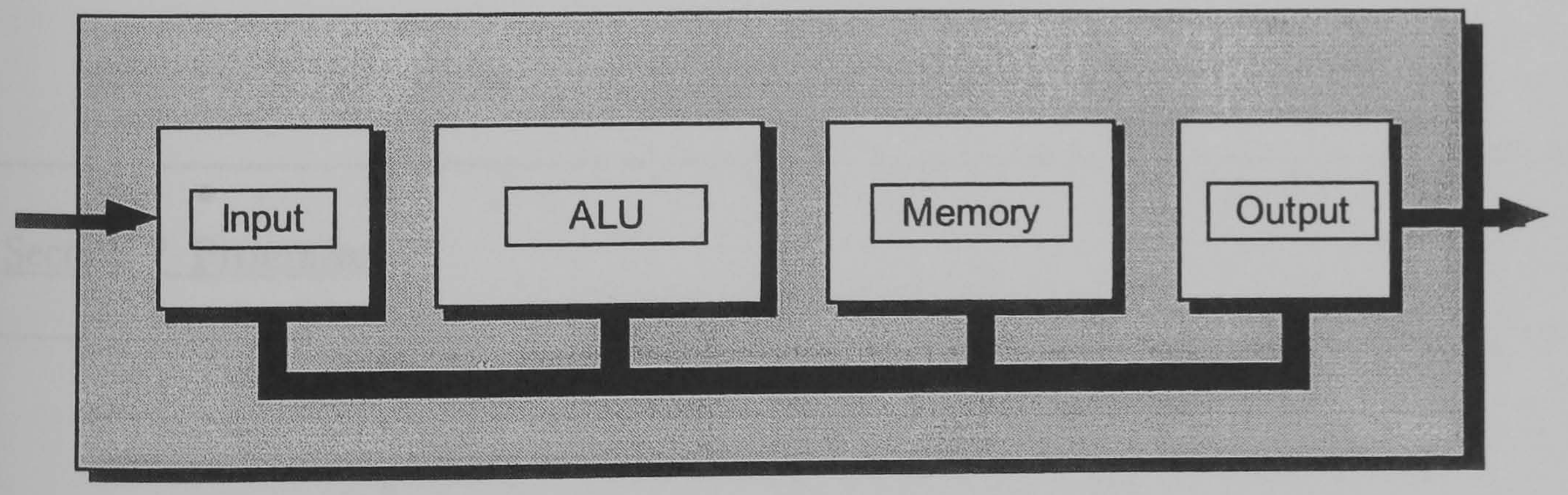
Section 2 Functions



1-4

Add your own notes in the space provided

Section 3 Elements



1-2

Add your own notes in the space provided

Section 4 Memory

	🗎1-3 Add your own notes in the space provided

Section 5 Arithmetic Logic Unit (ALU)

	🗎1-2 Add your own notes in the space provided

Section 6 Input/Output

	🗎1 Add your own notes in the space provided

Section 7 Programs

	🗎1-2 Add your own notes in the space provided

Chapter 3 Computer Instructions

Section 1

No notes

Section 2 Programs (continued)

	1 Add your own notes in the space provided

Section 3 Instruction Format

	1-4 Add your own notes in the space provided

Section 4 Storage of Programs

	1 Add your own notes in the space provided

Chapter 4 How instructions are carried out

Section 1

No notes

Section 2 Control Unit

1

Add your own notes in the space provided

Section 3 Fetch & Execute

1-3

Add your own notes in the space provided

Section 4 Control Signals

Unit	Control Signals
Memory	
Input	
Output	
ALU	

1-5

Add your own notes in the space provided

Section 5 Instructions & Examples

1-2

Add your own notes in the space provided

Chapter 5 Summary

Section 1 Objectives

No notes

- End of Module -

Additional Notes and Comments

Appendix K

EDEC Digital Design Theme
Introduction to Assembly Language

Workbook

Date – 5 December 1997
Author – David Brittle

1) Aims of Module

This module introduces...

The concept of assembly language
The architecture of the Motorola 68000
A few of the more common 68000 instructions, including conditionals.

When you have completed it you should be able to start programming the M68000.

2) Module Prerequisites

Completion of the previous module, *Introduction to Computer Systems*.

3)Tools and Equipment

None.

4) The Workbook

This is a workbook for you to log results and notes in whilst you progress through the course material. This book will also act as a source of reference in the future.

in the right hand margin indicates that there is interaction in the course material.

Chapter 1 Introduction to Assembly Language

Section 1 Introduction

Address	Machine code	Label	Mnemonic	Operand
		Assembly code		
0	1006		IN	X
1	1007		IN	Y
2	3006		MOVE	X, ACC
3	5007		ADD	Y, ACC
4	4008		MOVE	ACC, SUM
5	2008		OUT	SUM
6		X	DS	
7		Y	DS	
8		SUM	DS	

3-7

Add your own notes in the space provided

Chapter 2 The M68000

Section 1 The M68000

2-11

Add your own notes in the space provided

Chapter 3 Conditionals

Section 1 Branching

1-7

Add your own notes in the space provided

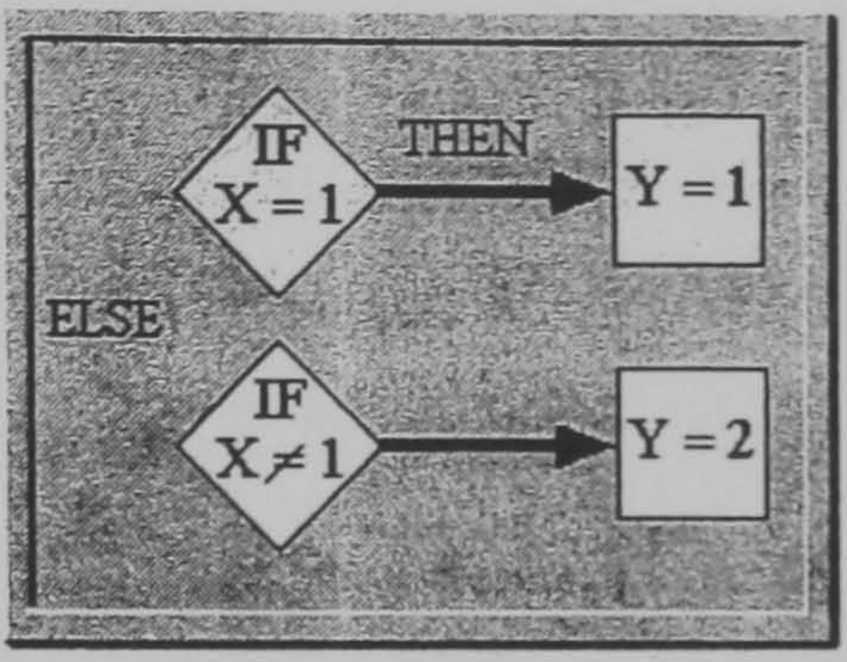
Conditional Behaviour

How does the M68000 implement conditional behaviour ?

A conditional statement in a high level computer language would look like this:

```
IF X = 1  THEN  Y:= 1
          ELSE  Y:= 2;
```

Press here



On the 68000 a special register called the Condition Code Register (CCR), is used to implement conditional behaviour.

The CCR is made up of a set of flag bits which are set or reset after every instruction.

			X	N	Z	V	C	CCR register
7	6	5	4	3	2	1	0	← Bit number

Chapter 3 Section 1 Page 2

Chapter 4 Summary

No notes

- End of Module -

Additional Notes and Comments

Appendix L

Student Comments – Case Study 2

Student 5293504
Good.

Student 5293504
The EDEC program was very useful, but did not prepare me for the practical lab sessions.

Student 5293504
On Internet - "Check e-mail, looking for useful websites"
The learned work did not go in depth enough and specific enough to be of any great value in practise - a good background. On computers - "Depends on deadlines - I use them as little as possible." On Internet - "Just for e-mail and booking coach tickets."
I don't like computers, it's nothing personal.

Student 5293504
The system was quite useful in showing the basics needed for the lab sessions. Although it didn't show everything that was needed it gave a basic understanding to give a headstart in the labs. Sometimes moved too fast, didn't give time to read.

Student 5293504
To check e-mails. The modules were good except 1 or 2 more could have made things easier.

Student 5293504
Easy to navigate. - I own a computer and use it every day - On Internet "e-mail"

Student 5293504
On Internet - "Generally researching for coursework." On EDEC instructions - "Sometimes too much at once." "Sometimes text was too fast." "On images to support text - "Sometimes it took your mind off the text & you had to repeat it.

Student 5293504
It looks a bit Windows 3.1ish. Colour scheme isn't great.

Student 5293504
On EDEC as preparation for labs - "Perhaps an assembly language as well would help!"

Student 5293504
On textbooks - "boring"

Student 5293504
You can study at your own pace and you don't fall asleep like you do in lectures.

Student 5293504
The response is fixed. If one does not understand there is no further help. The animations were ocassionally too long.

Student 5293504
On Internet - "Mainly just looking at e-mails or surfing the Web; i.e. no project work."

Appendix M

Case Study Three, 26th April 2002

Introduction to VHDL

Student Number:

This sheet is intended to identify the degree of confidence that you have in the learning covered by the EDEC modules.

Please tick one box only in each case.

Topic / Task	Very confident	Confident	Some confidence	Little confidence	No confidence at all
Define a finite state machine.	☐	☐	☐	☐	☐
Describe the architecture of a finite state machine.	☐	☐	☐	☐	☐
Produce a state transition network to describe a simple finite state machine.	☐	☐	☐	☐	☐
Convert the state transition network for a Moore machine into a Mealy machine.	☐	☐	☐	☐	☐
Implement a simple finite state machine in VHDL.	☐	☐	☐	☐	☐
Describe two situations in synchronous data transfer where a common clock between subsystems would be inappropriate.	☐	☐	☐	☐	☐
Give an example where asynchronous transfers are better than synchronous transfers.	☐	☐	☐	☐	☐
Implement a multiple handshaking routine in VHDL.	☐	☐	☐	☐	☐
Describe a testbench.	☐	☐	☐	☐	☐
Whilst exhaustive testing is impractical, describe the two elements of a testbench which must undergo testing.	☐	☐	☐	☐	☐
Design a testbench for an ALU using VHDL.	☐	☐	☐	☐	☐

Thank you for your time.

Appendix N

Observation Notes –Case Study 3

22nd March 2002

Introduction to VHDL
2hrs duration (9am – 11am)
Working Sample Size – 11 students

Notes

- EDEC workbooks are used as evidence for assessment along with VHDL simulator based assignment.
- Standard EDEC workbook being used for this course.
- Project consists of 6 EDEC modules and programming simulator package:
  - Combinatorial Circuits
  - Storage and Clocked Devices
  - Concurrent Operations
  - Finite State Machines
  - Data Transfers and Handshaking
  - Test Benches

Observations

9.10am
- Observe a relaxed, informal learning environment.
- Lecturer introduces EDEC and timescales
- All students asked to initiate module launcher.
- Lecturer reviews the structure of the EDEC interface with students.
- **Note:** Students last exposed to EDEC in 2nd year of degree.

9.15am
- Lecturer clearly indicates that EDEC modules for this part of the course will not be supported by lectures or other means.
- Students encouraged to take responsibility for their own learning and time management for these modules.
- Lecturer highlights the need for students to take their time in moving through the modules and avoid 'skimming'. Stresses the fact that they will *"...have to go over some material more than once."*
- Lecturer stresses the link between the modules and need for appropriate note taking via the accompanying workbook.

9.40am
- Students having problems with the help files within the modules.
- Lots of group co-operation evident within the class.
- Some students choosing to review the EDEC workbook prior to commencing.

9.45am
- All students observed to be working through the first module.
- A degree of discussion is observed among students regarding problems with the EDEC interface.
- One student observed to be clicking a number of times on a section of blue text which he misinterprets as being a hyperlink.

9.50am
- One student asks the lecturer how many modules must be completed during this session.
- Lecturer advises all students that the six modules should be completed within two to three weeks.
- Most students observed to be using workbooks alongside EDEC screens.
- All students are well focused on the EDEC materials at this stage.
- Some evidence of 'back tracking' observed. This can be linked to the navigation design of the module (Combinatorial Circuits).
- All students working independently at this stage.

10.00am

- Multiple reviews of material more apparent here than at institution 2.
- Rigorous review of programming screen evident.
- Multiple clicking on areas of the screen observed as evidence of confusion as to links/interactive elements.
- No requests for support from lecturer at this stage.
- Lecturer going round students on an individual basis.

10.05am

- Some student co-operation in learning now apparent.
- Some of the students' discussion is outwith the scope of EDEC, although generally course related.
- Lecturer highlights the green links within the screens to students. Many student were unaware that these provided additional pop-up notes.

10.10am

- One student preferring to take own notes in lieu of the EDEC notebook.
- Students generally taking considerable time to read all text within each screen. Some taking notes verbatim from screen to workbook.
- Many students copying programming code directly from screen to workbook.
- Generally observed lots of direct transfer of information from screen to workbook.

10.20am

- Time taken to process each screen observed to be far greater than that observed at institutions 1 and 2.
- Flexible learning environment allows students to come and go as they please during session.
- Observed the impact of textual information as paramount to students' priority in learning over interactive and visual elements for this module.

Observation Notes

12th April 2002

Introduction to VHDL
2hrs duration (9am – 11am)
Working Sample Size – 13 students

Observations

9.15am

- Administer confidence log 1.

9.20am

- **Note**: List Remember to list hyperlink to tutorial web-site in LRQ.
- Lecturer indicates that only outside support to EDEC for the VHDL part of the course is provided by this hyperlink.

9.30am

- Students observed to be working independently.
- One student indicates a preference for own notes over the workbook to the lecturer (this is an assessable element).

9.35am

- Students observed to be meticulous in their note taking (assessable), particularly from the green pop-up information fields within the package.
- Considerably more time spent on each screen than observed during evaluations at institutions 1 and 2. Students much more meticulous and spending much more time on static screens (particularly pages with programming code).

9.45am

- A very high degree of information processing/note taking generally apparent on pages with programming code/screen notes.
- There is evidence of some students directly transferring screen information to their notes. Is this how the material is expected to be used?

9.50am

- Students generally observed to be highly motivated by the task and its relevance (assessment value).

- All students are observed to be proceeding at their own pace with no evidence of peer influence on pace.
- **Note**: are 3 weeks sufficient for completion of 6 modules? What expectation is their for self-study?

9.55am

- One student observed making multiple reviews of animation (module 1 – circuit architecture).

10.00am

- All students observed to be well focused on task.

10.15am

- One student observed to be 'skimming' animated element in order to get to information.
- Observed some students initiating simulator package alongside EDEC material. This caused problems for a number of students. Lecturer indicated that this was badly designed within the EDEC package.
- Some students using printer to 'screen –dump EDEC pages where necessary.

10.20am

- A fair degree of student cooperation/support is now evident. This is largely based on technical issues such as screen minimisation/navigation etc. as against content/knowledge related issues.

10.25am

- Students observed to be using EDEC package in a more sophisticated manner (i.e. non-linearly).

10.35am

- Lecturer stresses the importance of the 'Coursework Specification' to students in order to highlight the time limitations in covering the EDEC modules.
- Students encouraged to have completed all modules by next week (most students on modules 2/3).
- Students encouraged to research and implement their own VHDL programming beyond the scope of the examples given within the EDEC material.
- Lecturer supports observation that some students are copying notes verbatim from the screen.

10.40am

- Started focus group with students.

Observation Notes

26th April 2002

Introduction to VHDL
2hrs duration (9am – 11am)
Working Sample Size – 11 students

Observations

9.10am

- Discussion with lecturer indicates that students are at various stages. Some still working on EDEC material.
- Lab environment very informal, with students starting in their own time.
- Lecturer supporting students on a one to one basis.

9.15am

- Observed signs of students requiring more time to complete the EDEC material than allocated within timetable. Is self-study taking place to the extent of the lecturer's expectation.

9.20am

- Lower level of motivation evident at the start of today's session.
- **Note**: This may be due to student starting project on simulator without the prompt/goal to complete as in the EDEC modules.

9.25am

- Some observed evidence of students switching their learning between EDEC package and simulator package.

- Some discussion raised with lecturer regarding the use of additional zip files which are within the course web-site. Students regard problems as an EDEC/VHDL problem whereas lecturer regards it as a file management issue.

9.30am

- Lecturer stops class to establish goals for project and encourages student to have completed all EDEC work by early today.

9.40am

- Students observed to be co-operating on technical issues regarding program files and simulator.

9.45am

- One student observed taking notes whilst animation is running. Definite sign that text rich info has taken precedence over animated material.
- Note: This student went on in the mini group to promote the animated elements in terms of his learning.

9.50am

- Lots of peer co-operation is evident on practical issues for the project part of the assignment.
- Some discussion between students indicates a tactical approach to their learning – what to do to get a good mark.

10.40am

- Started focus group with students.

Appendix O

Student Comments – Case Study 3

97048775
"EDEC is a good idea. Just needs more work on it. Developers should consult/interact with users to know how they take to it and use it. They would see what the user finds particularly good and build those into the rest of the programme. If that happened then the 'visual learner' would find it a very useful source of learning material!"

"I'm more of a visual learner."
"Hard to understand lecture references. Meant own research needed."

On EDEC

- "Fairly obvious navigation."
- Sufficient instructions – "albeit a little thin."
- "Hyperlinks were not obvious, looked more like they were emphasised – colour difference."
- "Some parts too textually displayed."
- Graphics – "Could be better. A more simplistic approach would be good – clearer!"
- Too much information on each page – "Definitely, making it more concise would be great!"
- Overall – "Would be good if it was a little better to use overall.
- Strongly disagreed that he would use the system again... "in its present form."

98078452
"EDEC was possibly the most uninteresting, boring and useless computer package that I have ever used. At the beginning I tried to understand and motivate myself to what was going on, but as I went through the package I just could not see the purpose of it at all.

Personally, I feel that it is of use only to lecturers, where they can just take a back seat away from teaching. Some students will possibly prefer this method but the amount of learning they will gain is very debatable. Improvements that could be made is definitely more interaction in the package."

On lectures – "Original way and best, possibly more interaction would be good.
On EDEC – "A bit pointless really."
On use of Internet – "Usually for e-mail/news/latest sport news."
On computer packages – "If they're short and interesting."
On computer games – "Very rarely. Not very good at them."
On Internet and learning – "Can be, but is extremely dubious."
"I'm not EDEC's biggest fan."
On helpfulness of graphics – "Sometimes quite pointless."
On helpfulness of interactive elements – "Once again of not much use."
On animations – "At times too fast, at times too slow."
On control, start/stop – "Could help."
"If animations too fast, reading screen at same time became difficult."
"Quite pointless. Lecturers take back seat student learns nothing!"
Would you use it again – "Hopefully not!"
"All the time, too much useless info."

97044114
"I generally found EDEC very time consuming. Time spent reading screen, then taking notes could have been utilised better. Handout sheets with printed notes or screen captures from EDEC would be more useful as students could read notes and highlight important points. However the animations were very useful but were either too fast or too slow."

"Handout notes could be more useful."

97046595
"Simple with very little in-depth explanations."
"Material was a good base to start a study into a subject."
"Some examples required to be run several times before they were fully understood."
"Would be better if the animation could be paused."

99006831
"It was very laborious and required time to obtain relevant notes."
"It took a long time to make notes on the information provided."
"However, each student has their own opinion. They would have to try it for themselves."

99015488
"Some pop-up boxes were not initially found."
"Easy to read, but uncomfortable to stare at a screen for long periods."
"Need to assign degree of relevance to all info displayed."
"Learning was not intuitive."
"Looked like something from the Windows 3.1 era."
"Easy to use, nice pictures/animations but didn't learn much."

Course Deliverer Interview

Case Study 3 – 6th June 2002

1. Why do you choose to use EDEC in your teaching?
2. What is the intention of the VHDL course in terms of learning?
3. What contribution do the EDEC modules make to the course?
4. What steps if any have been taken to integrate the EDEC material into your teaching?
    - Did you find it easy to integrate?
5. What could be done (by tutors/system) to make the system easier to integrate?
6. Has your use of EDEC evolved over the last 5 years (if so, how)?
7. Has Web delivery affected your use of EDEC?
8. How do you use the Web in your teaching?
9. How do you envisage your future use of EDEC material?
10. Are there any elements of the EDEC material which could be changed to improve learning?

Observation Protocol – University of Glasgow, June 2004
EDEC - Number Systems

Date:	**8-6-04**
Student Number:	**0108299**
Gender:	**Male**
Start Time:	1:33: 40.

Other Resources Used:

River Past – Screen Recorder software
Digital voice recorder
Headset microphone
Calculator (for student use)
Workbook (for student use)
Pen (for student use)
Paper (for student use)

Student Preparation Checklist:

1. Discuss research procedure with student.	✓
2. Gain student's consent for procedure (ethics).	✓
3. Issue headset microphone to student.	✓
4. Issue pen and paper to student.	✓
5. Set up WebCam.	✓
6. Start voice recorder.	✓
7. Start screen recorder software.	✓

Additional Comments

Observable evidence of skimming and lack of awaren
interest in how package worked and correctness
of answers. Check with pre/post-test.
Very uniform/linear approach taken.
Seemed vague and uncertain as to the qualit
of learning being obtained.

Chapter 1 / Section 1 / Page 1 (Title page)

Chapter 1 / Section 1 / Page 2 (Intro. – Using this Package)

Start Time:

Skimmed through.

Chapter 1 / Section 1 / Page 3 (Intro. – Using this Package)

Start Time: 1:34:05 .

Reading objectives.

Chapter 1 / Section 1 / Page 4 (Intro. – Using this Package)

Start Time: 1:34:45

- Reading text
- Trying interactive question
- Wrong three times
- Didn't recognise interactive section – dragging works.
- Required prompting for dragging

Chapter 1 / Section 1 / Page 4 (Intro. – Using this Package)

Start Time:

Chapter 1 / Section 2 / Page 1 (Intro. – Binary Numbers)

Start Time: 1:36:50

Intricate animation

Confusion evident

Chapter 1 / Section 2 / Page 2 (Intro. – Binary Numbers)

Start Time: 1:37:35

- Reading ~~text~~ aloud.
- Trying interactive section
- Correct first time

Chapter 1 / Section 2 / Page 3 (Intro. – Binary Numbers)

Start Time: 1:38:16

- Reading text aloud.
- Prompted to go to previous page
  — didn't go — guessed answer.
- didn't try second Q.

Chapter 1 / Section 2 / Page 4 (Intro. – Binary Numbers)

Start Time: 1:39:00.

- Reading text aloud
- Brief read and quick answer
  1:39:26 Correct

Chapter 1 / Section 2 / Page 5 (Intro. – Binary Numbers)

Start Time: 1:39:35

Note: Check for interaction with red text

Read text

Initiate animation

No interaction with red text.

verbalising before end of animation

unclear

Chapter 1 / Section 2 / Page 6 (Intro. – Binary Numbers)

Start Time: 1:40:33

Note: Check for use of toolbox

- Reading aloud
- Quick attempt at answer
- No attempt to verify answer
  unaware – return key.

Chapter 1 / Section 2 / Page 7 (Intro. – Binary Numbers)

Start Time: 1:41:14

Skimmed

miss animation

Chapter 1 / Section 2 / Page 8 (Intro. – Binary Numbers)

Start Time: 1:41:38.

Note: Check for use of toolbox

- Using paper to calculate
- Hasn't noticed toolbox.
- Evidence of skimming
- Working entirely on paper at this point 1:42:36.
- No verification of answer.

Chapter 1 / Section 3 / Page 1 (Intro. – Hexadecimal Numbers)

Start Time: 1:42:45.

- Reading text aloud.
- Initial animation
- Watching animation to end.
- Staying / reflecting on answer
  - don't know where it comes from

Chapter 1 / Section 3 / Page 2 (Intro. – Hexadecimal Numbers)

Start Time: 1:44:07.

Reading text aloud

- Initiate interactive element.
- Has got drag and drop.
- All answers correct.

Chapter 1 / Section 3 / Page 3 (Intro. – Hexadecimal Numbers)

Start Time: 1:44:58

Reading questions aloud.

1 — Correct.

2 — Correct - degree of guessing

3 - Correct.

Chapter 1 / Section 3 / Page 4 (Intro. – Hexadecimal Numbers)

Start Time: 1:46:08

- Reading text aloud.
- Working through problem on screen (static)
- Initiate animation.
- Reviewed fully (anim).

Chapter 1 / Section 3 / Page 5 (Intro. – Hexadecimal Numbers)

Start Time: 1:47:06

Note: Check for use of toolbox

Working out problem on paper with pen in lieu of screen

- No use of package at this stage
- No use of toolbox.
- No attempt to verify answer (return).

Chapter 2 / Section 1 / Page 1 (Negative Numbers – Sign and Magnitude)

Start Time:

Chapter 2 / Section 1 / Page 2 (Negative Numbers – Sign and Magnitude)

Start Time: 1:48:10

- Quick scan read
- Eager to get onto answering question
- Trial and error evident
  - Moved on after correct answer with a little reflection

Chapter 2 / Section 2 / Page 1 (Negative Numbers – Complementary Numbers)

Start Time: 1:49:20.

- Reading text aloud.
- Initiate animation
- Reflection on animation (silence

No review

Skimming

Chapter 2 / Section 2 / Page 2 (Negative Numbers – Complementary Numbers)

Start Time: 1:50:00

- Quick scan of text
- attempt to answer Q. very quickly

Skimming

Chapter 2 / Section 2 / Page 3 (Negative Numbers – Complementary Numbers)

Start Time: 1:50:36.

- Read text aloud.
- animation reviewed

Chapter 2 / Section 2 / Page 4 (Negative Numbers – Complementary Numbers)

Start Time: 1:51:15.

- Read text aloud
- Animation initiated
- Watching animation (silent)
- Review animation – didn't understa
- Using multiple reviews of animation.
- Reflecting on points he doesn't understand.

Chapter 2 / Section 2 / Page 5 (Negative Numbers – Complementary Numbers)

Start Time: 1:54:00.

Note: Check for use of toolbox

- Reading text
- Moves to paper and pen for calculation
- No attempt to check answer (return).

Chapter 2 / Section 2 / Page 6 (Negative Numbers – Complementary Numbers)

Start Time: 1:54:55

- Quick skim over text.
- Moving to interactive section although unsure
- can't find button (hits 'off')
- Evidence of trial and error.
- Back to paper.
- Definite trial and error
- Arrived at answer through guessing.

Chapter 2 / Section 2 / Page 7 (Negative Numbers – Complementary Numbers)

Start Time: 1:56:38

- Straight to paper because its a calculation
- Little interaction with package.
- Running animation, although evidence of frustration, losing interest.

Chapter 2 / Section 2 / Page 8 (Negative Numbers – Complementary Numbers)

Start Time: 1:58:00.

'What am I doing now'

* Quick skim of text.

rote response to animation

- watching animation while confirming 'I understand that'
- Evidence of losing interest in animation.

-

Chapter 2 / Section 2 / Page 9 (Negative Numbers – Complementary Numbers)

Start Time: 1:59:27.

Note: Check for use of toolbox

- General lack of ~~x~~ interface with package
- Straight to paper for calculation with lack of use of package
- No attempt to check answer

Chapter 3 / Section 1 / Page 1 (Multiplication & Division - Binary)

Start Time:

Chapter 3 / Section 1 / Page 2 (Multiplication & Division - Binary)

Start Time: 2:00:36

- Reading aloud - new topic

- Initiating top animation
- " " 2nd "
with little time to reflect

Chapter 3 / Section 1 / Page 3 (Multiplication & Division - Binary)

Start Time: 2:01:43.

- Reading aloud.
- Skimming
- Intuitive animation
- Little learning evident (silen
- reflecting on text

Chapter 3 / Section 1 / Page 4 (Multiplication & Division - Binary)

Start Time: 2:02:44.

Note: Check for use of toolbox

- Straight to paper for calculation
- No use of toolbox - seems unaware of it (consistent ~~&~~
- Enters answer after some reflection back at package
- Not attempt to check answer

Chapter 3 / Section 1 / Page 5 (Multiplication & Division - Binary)

Start Time: 2:04:00

- Skim reading
- initial animation 1
- " " 2

little reflection - skimming
no real interaction / learn
evidence

Chapter 3 / Section 1 / Page 6 (Multiplication & Division - Binary)

Start Time:

Observation End Time:

Total Time Observed: 2:04:45

Student 1 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	y	y	-	-	
1.1.3	y	-	-	-	

Student 1 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	-	y	-	-	
1.2.5	y	y	y	-	-	
1.2.7	y	-	y	-	-	
1.3.1	y	y	y	-	-	
1.3.4	y	y	y	-	-	Predicts animation.
2.2.1	y	y	y	-	-	
2.2.2	y	y	y	-	-	
2.2.3	y	y	y	-	-	
2.2.4	y	y	y	-	y	Predicts animation.
2.2.7	y	y	y	-	-	Predicts animation.
2.2.8	y	y	y	-	-	
3.1.2	y	y	y	-	-	
3.1.3	y	y	y	-	-	
3.1.5	y	y	y	-	-	

Student 1 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	-	-	-	-	y	
1.2.2	y	y	-	-	-	-	y	
1.2.3	y	-	-	-	-	-	y	
1.3.2	y	y	y	y	-	-	-	
1.3.3	y	y	y	y	-	-	-	
2.1.2	y	y	-	-	y	-	y	
2.2.6	y	y	-	-	y	-	y	

Student 1 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	y	y	y	y	-	-
1.2.6	y	y	y	y	y	-	-
1.2.8	y	y	y	y	y	-	-
1.3.5	y	y	y	y	y	-	-
2.2.5	y	y	y	y	y*	-	-
2.2.9	y	y	y	y	y	-	-
3.1.4	y	y	y	y	y*	y	-

Appendix R

Student 2 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	y	-	-	-	
1.1.3	y	-	-	-	

Student 2 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	-	y	y	-	
1.2.5	y	y	y	y	-	
1.2.7	y	y	y	-	-	
1.3.1	y	y	y	-	-	
1.3.4	y	y	y	yyy	yy	
2.2.1	y	y	y	y	-	
2.2.2	y	y	y	y	-	
2.2.3	y	y	y	y	-	
2.2.4	y	y	y	y	-	
2.2.7	y	-	y	yy	-	
2.2.8	y	y	y	y	-	
3.1.2	y	y	y	yy	-	
3.1.3	y	y	y	-	-	
3.1.5	y	y	y	-	-	

Student 2 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	y	y	-	-	-	
1.2.2	y	y	y	y	-	-	-	
1.2.3	y	y	y	y	-	-	-	
1.3.2	y	y	y	y	y	yy	-	
1.3.3	y	-	y	y	-	-	-	
2.1.2	y	y	y	y	-	-	-	
2.2.6	y	y	y	y	y	-	-	

Student 2 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	y	y	y	y	-	yyy
1.2.6	y	-	y	y	y	y	yy
1.2.8	y	-	y	y	y	y	y
1.3.5	y	y	y	y	y	yyyyyy	yyyyyy
2.2.5	y	-	y	y	y	-	-
2.2.9	y	y	y	y	y	yyy	-
3.1.4	y	y	y	y	y	y	-

Appendix R

Student 3 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	y	y	-	-	
1.1.3	y	y	-	-	

Student 3 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	y	y	yy	-	
1.2.5	y	y	y	y	-	
1.2.7	y	-	y	-	-	
1.3.1	y	y	y	-	-	
1.3.4	y	y	y	yy	y	
2.2.1	y	y	y	y	-	
2.2.2	y	y	y	y	-	
2.2.3	y	y	y	y	y	
2.2.4	y	y	y	yyyy	y	
2.2.7	y	y	y	yy	y	
2.2.8	y	y	y	yy	yy	
3.1.2	y	y	y	yy	-	
3.1.3	y	y	y	yyyyy	y	
3.1.5	y	y	y	yy	-	

Student 3 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	y	y	-	-	-	
1.2.2	y	y	y	y	yy	y	-	
1.2.3	y	y	y	y	-	-	-	
1.3.2	y	y	y	yyyy	y	y	-	
1.3.3	y	-	y	y	-	-	-	
2.1.2	y	y	y	y	yy	-	y	Reflect
2.2.6	y	y	y	y	yy	y	y	Reflect

Student 3 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	y	y	y	y	y	
1.2.6	y	-	y	y	yyy	yyy	yyy
1.2.8	y	y	y	y	y	-	-
1.3.5	y	y	y	y	yyyy	yyyy	yy
2.2.5	y	y	y	y	yyyy	yyy	y
2.2.9	y	y	y	y	y	y	-
3.1.4	y	y	y	y	yy	yy	y

Appendix R

Student 4 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	-	-	-	-	Missed screen by accident.
1.1.3	y	y	-	-	Problems with interface.

Student 4 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	y	y	y	-	
1.2.5	y	y	y	-	-	
1.2.7	y	y	y	-	y	
1.3.1	y	y	y	yy	y	
1.3.4	y	y	y	y	-	Predicts animation.
2.2.1	y	y	y	y	-	
2.2.2	y	y	y	yy	y	
2.2.3	y	-	y	yy	y	
2.2.4	y	y	y	-	-	
2.2.7	y	y	y	-	-	
2.2.8	y	-	y	-	y	
3.1.2	y	y	y	-	-	Limited analysis.
3.1.3	y	y	y	-	-	
3.1.5	y	y	y	-	-	

Student 4 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	y	y	-	-	-	
1.2.2	y	y	y	y	-	-	-	
1.2.3	y	-	y	y	-	-	-	
1.3.2	y	y	y	y	y	-	-	
1.3.3	y	-	y	y	-	yyy	y	
2.1.2	y	y	y	y	-	y	y	
2.2.6	y	y	y	y	-	-	y	

Student 4 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	-	y	y	y	-	y
1.2.6	y	-	y	y	y	y	yyy
1.2.8	y	y	y	y	y	-	yy
1.3.5	y	y	-	y	y	y	y
2.2.5	y	y	-	-	-	-	-
2.2.9	y	y	-	-	-	-	-
3.1.4	y	y	-	-	-	-	-

Appendix R

Student 5 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	y	y	y	-	
1.1.3	y	-	y	-	

Student 5 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	y	-	y	-	
1.2.5	y	y	-	-	-	
1.2.7	y	y	-	-	-	
1.3.1	y	y	y	-	-	
1.3.4	y	y	y	-	-	
2.2.1	y	y	y	-	-	
2.2.2	y	y	y	-	-	
2.2.3	y	y	y	-	-	
2.2.4	y	y	y	-	-	
2.2.7	y	y	y	-	-	
2.2.8	y	y	y	-	-	
3.1.2	y	y	y	-	-	
3.1.3	y	y	y	-	-	
3.1.5	N/A	N/A	N/A	N/A	N/A	

Student 5 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	-	-	-	yy	y	
1.2.2	y	y	-	-	-	yy	y	
1.2.3	y	y	-	-	-	-	y	
1.3.2	y	y	-	-	-	y	y	
1.3.3	y	y	y	y	-	-	y	
2.1.2	y	y	-	-	-	-	y	
2.2.6	y	y	-	-	-	-	y	

Student 5 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	y	-	-	-	-	-
1.2.6	y	y	-	-	-	-	-
1.2.8	y	y	-	-	-	-	-
1.3.5	y	y	-	-	-	-	-
2.2.5	y	y	-	-	-	-	-
2.2.9	y	y	-	-	-	-	-
3.1.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Student 6 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	y	-	-	-	No verbalising took place during screen.
1.1.3	y*	-	-	-	* Problems with interface – incomplete model.

Student 6 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	y	y	-	-	
1.2.5	y	-	y	yy	yyy	
1.2.7	y	y	y	-	-	
1.3.1	y	y	y	-	-	
1.3.4	y	y	y	y	y	
2.2.1	y	y	y	-	-	
2.2.2	y	y	y	-	-	
2.2.3	y	y	y	-	y	
2.2.4	y	-	y	-	y	
2.2.7	y	-	y	-	-	
2.2.8	y	y	y	-	yy	
3.1.2	y	y	y	-	-	
3.1.3	y	-	y	-	yyyy	
3.1.5	y	-	y	-	-	

Student 6 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	y	y	-	-	-	
1.2.2	y	-	y	y	-	-	-	
1.2.3	y	y	y	y	-	-	-	
1.3.2	y	y	y	y	-	-	-	
1.3.3	y	y	y	y	y	-	-	
2.1.2	y	y	y	y	-	-	-	
2.2.6	y	-	y	y	y	-	y	

Student 6 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	y	-	-	-	-	-
1.2.6	y	y	y	y	y	yy	-
1.2.8	y	y	y	y	y	-	-
1.3.5	y	y	y	y	y	yy	yy
2.2.5	y	y	y	y	y	y	yy
2.2.9	y	-	y	y	y	y	-
3.1.4	y	y	y	y	y	yy	yyyy

Appendix R

Student 7 – Model 1 Type Screens Analysis					
Screen No.	Read text	Orientate	Reflection	Feedback loop	Notes
1.1.2	y	-	-	-	
1.1.3	y	-	-	-	

Student 7 – Model 2 Type Screens Analysis						
Screen No.	Read text	Orientate	Process Animation	Reflection	Feedback Loop	Notes
1.2.1	y	y	y	y	yyy	
1.2.5	y	-	y	y	y	
1.2.7	y	-	y	y	y	
1.3.1	y	y	y	y	y	
1.3.4	y	-	y	-	yy	
2.2.1	y	-	y	-	-	
2.2.2	y	-	y	-	-	
2.2.3	y	-	y	-	-	
2.2.4	y	-	y	-	-	
2.2.7	y	-	y	y	-	
2.2.8	y	y	y	y	-	
3.1.2	y	-	y	y	-	
3.1.3	y	-	y	-	-	
3.1.5	y	y	y	y	-	

Student 7 – Model 3 Type Screens Analysis								
Screen No.	Read text	Orientate	Analyse concept	Test concept	Reflection	Feedback loop	Trial and error	Notes
1.1.4	y	y	y	y	-	-	-	
1.2.2	y	y	y	y	y	y	-	
1.2.3	y	-	y	y	-	-	-	
1.3.2	y	y	y	y	-	yyyy	-	
1.3.3	y	-	y	y	-	-	-	
2.1.2	y	y	y	y	-	-	-	
2.2.6	y	-	y	y	-	-	-	

Student 7 – Model 4 Type Screens Analysis							
Screen No.	Read text	Orientate	Analyse concept	Calculate	Test concept	Reflection	Feedback loop
1.2.4	y	-	y	y	y	-	yyy
1.2.6	y	-	y	y	y	yy	y
1.2.8	y	y	y	y	y	-	-
1.3.5	y	-	y	y	y	-	y
2.2.5	y	-	y	y	y	-	yy
2.2.9	y	-	y	y	y	-	y
3.1.4	y	-	y	y	y	-	y

Appendix S

Case Study 4 - Interview Questions

1. Did the think-aloud interfere with your ability to learn the material?
2. Had you come across the topic covered by the EDEC module before?
3. How would you say you prefer to learn?
4. What did you think was good about the resource?
5. Did you think that anything was poor about it?
6. What did you think of the user interface?
7. Do you like to learn using this type of resource?
8. Do you have any suggestions that might make the module better as a learning resource?

Appendix T

Student Comments – Case Study 4

108092

On Internet - "Good for general knowledge."
On EDEC – "Depending on the question, sometimes I didn't know if I was to do it, or if it was an example."
The language was clear. - "Basic language clear, but some tricky bits."
There was too much information on each page for me to remember. - "Felt some things were too much."
Overall, the system had an attractive presentation. - "Basic but effective."

108299

"Overall a good package. Just to control the speed in two or three occasions would have been helpful."

107622

On use of Internet – "Sometimes lecture notes too intense, need simplified stuff."
"Use the computer every day."
"Have broadband so use it every day cos I pay for it, plus it's there so why not use it."
"I use the Internet a lot. Always looking into it for social and academic work."
Parts of the system were difficult to use. – "Moved too fast, i.e. animations."
The system helped me if I got confused. – "Had to do some paperwork thinking rather than computer help."
I would recommend the system to other students. – "Think if there was more controlability for the user it would be much better."

108134

"I believe the more traditional methods of learning are more appropriate for me, although I would use computer based learning if I had to."
On lectures – "Gives me a foundation to build on."
On textbooks – "Prefer written text in a book as opposed to on a screen."
On EDEC – "Not comfortable with this."
On notes from lectures/labs – "Good back up of key points from lectures."
On borrowed notes from someone else – "Their key points might be different from mine."
On discussion with tutor/lecturer – "Lets me understand issues more."
On discussions with other students – "Lets me understand their points on issues."
On other resources (past papers) – "Informs me of what I could expect in exams and layout."
On using computers – "During the university terms."

7716471

"Very rusty on both Binary and Hex systems."
On lectures – "Need to be able to answer questions."
On EDEC – "Needs repetitive practice."

On discussion with tutor/lecturer – "Much better one to one."
On discussions with other students – "Got to watch who your discussion is with."
On other resources (past papers) – "Can you trust all sites. Sometimes spend much more time than necessary – textbook quicker."
"I think there comes a point where the system makes giant leaps e.g. it is possible to understand binary number systems but addition, subtraction, complements need shorter more explanatory steps – you have the feeling that at some point the program has just gone beyond your capabilities and motivation drops."

108022
"From a personal stance, I do not like using such packages to learn. This is mainly due to my short term recall memory. I find it easier reading from a book where I can easily flick between pages to recall what I have just read. I also like to interact with people, talking to them is far more beneficial to my learning as it is a manual process of communicating."
On discussion with tutor/lecturer – "Not always available."
On discussions with other students – "Good to get a more holistic understanding of any given topic."

107241
"I like using the package and found it interesting, difficult – but interesting. It was very easy to use and I liked the animations. When I am learning and I get to grips with a topic, doing a few examples helps me. I think it would be good if there were more example questions for students to work through."
On borrowed notes from someone else – "Difficult to understand someone else's notes."
On discussions with other students – "Discussing things with other students really helps me understand better."
On Internet – "Information is useful but it can sometimes be time consuming trying to find what your looking for."
"I use a computer every day during term time but less frequently during the holidays."
On Internet – "Again during term time. I use the internet to keep up to date with e-mails and course work etc. but during holidays I maybe only check my e-mails once a week."

107186
"Package was well presented, although only one example was given and if you were having some difficulties it wasn't very useful for helping out."
On lectures – "Depends on lecturer!."
On textbooks – "Good for information."
On own notes – "Can contain useful information."
On borrowed notes from someone else – "Often not relevant."
On discussion with tutor/lecturer – "Good for feedback."
On discussions with other students – "Helpful for generating ideas."
On other resources – "Can usually find what your looking for on the Internet."
I like to learn using computer packages. – "Can be useful but doesn't give out much help."

I like to play games on a computer. – "Only if I'm really bored!"
The Internet is very useful to my learning. – "There is loads of info, however, it's not always true/relevant."
I quickly became familiar with the system. – "After 2/3 pages."
The instructions on screen were sufficient when needed. – "Useful."
The system helped me if I got confused. – "There was very little help which it offered!"
It was clear to me where I was in the system. – "The sections were well titled."
It was clear how to move through the system. – "Good navigation buttons."
I think that the system is generally well structured. – "Good package."
I found that the information was presented consistently. – "Description, example, question."
It was obvious how to use the icons (buttons etc.). – "It took a while to figure it out."
The screen colour did not interfere with my reading. – "Not a problem."
I thought that the graphics were clear and helpful. – "Loved the wee car!!"
I found the animated elements too fast. – "Sometimes I had to replay them. Other times they were slow."
I felt that the animated elements would have been better if I could control speed and stop/start. – "Would have been helpful."
The animations were too long. – "Sometimes."
There was too much information on each page for me to remember. – "Took notes to help me."
I got what I wanted from the system quickly. – "Could skip forwards/backwards to sections I needed."
Overall, I liked using the system. – "Was very helpful."
I would recommend the system to other students. – "Good usable package."

Appendix U

Perry's Scheme of Intellectual and Ethical Development in the College Years

Dualism

1.Basic Duality: Assumption of dualistic structure of world taken for granted, unexamined. Right vs. wrong, we vs. others, good vs. bad, what They want vs. what They don't want. Will power and work should bring congruence of action and reward. Multiplicity not perceived. Self defined primarily by membership in the right and traditional.

Knowledge is an objective, definite, and organized body of facts that constitute the truth about a subject, to be distinguished from opinion, which is subject and cannot be proven as true.

2. Multiplicity: Pre-legitimate: Truth exists, but not all authorities are knowledgeable. Multiplicity perceived, but only as alien or unreal. As alien it assimilates easily to error and otherness: "others are wrong and confused." Assimilated to authority, it leads to opposition: "I am right; They (Authority) are needlessly confused."

As unreal, M is a mere appearance, e.g.: "They want us to work on these things to learn how to find the answer. Here Opposition sees Authority not as wrong but simply as failing in its mediational role.

In either case M is perceived, but it is not viewed as a signal of legitimate, epistemological uncertainty.

Knowledge consists of facts, principles, axioms, etc. that can be proved, although it may be difficult to carry out the proof. Overcoming this difficulty is the expert's challenge, and some are more expert than others.

3.Multiplicity Subordinate: Absolute truth has not been discovered, yet. Multiplicity perceived with some of its implications. Authority may not have the answers yet on some of it, perhaps because the relevant Absolutes are not yet in view. But trust in Authority, at least in the ideal, is not threatened. Exercises in M may be enjoyed or disliked. authority is presumed to evaluate them on skill of presentation (not on structural properties). Students may fear they are judged on glibness, influence, or pull.

Knowledge consists of facts, principles, axioms, etc. that can be proved, although it may be difficult to carry out the proof. The coherence and completeness of the system may vary across disciplines, some being more advanced than others.

Multiplicity

4a. Multiplicity Correlate: If authorities don't know the answer then any opinion is as good as another (and/or - see 4b) Duality restructured in complex terms: right-wrong vs. M. Absolutes may be doubted in M area or considered so inaccessible as to be impossible to bring to bear on human affairs in any reasonably foreseeable future. In M, therefore, "anyone has a right to his own opinions." M is acknowledged as relevant to self, by being confusing, liberating, intriguing, etc.

Knowledge is not secure but is any person's organization and interpretation of available information. One interpretation is as good as another.

4b. Relativism Subordinate: There is more than one approach to a problem. Relativism perceived in M and assimilated to Authority: That is, Authority can make judgments in M on discernible relations of propositions to each other (coherence) or to data (congruence). However, this is still "how they want us to think" rather than a consequence of the nature of all knowledge.(But people with power can assert their interpretations over those of others.)

Relativism

5. Relativism Correlate: Competing, or Diffuse: Relativism perceived as way of perceiving, analysing and evaluating, not because "They want us to think this way." be intrinsically. Authority perceived as (lower case) authority in R. In R Correlate, world divided into those areas where Authority has the answers (e.g. physics or morals) and those in which R must be used (e.g. English papers). In R Competing, R perceived as applying to whole world (with binary answers a sub-class), but this world view alternates with a previous one. In R Diffuse, the most fully developed of these structures, R is accepted generally but without implications for Commitment

Knowledge is always changing or subject to change. It can be shared but not "measured" or counted upon to remain the same

Commitments in Relativism
6. Commitment Foreseen: Subjectively choose among alternatives R accepted for all secular purposes including binary judgment and action. Commitment may be perceived as a logical necessity for action in an R world and/or"felt" as needed (with or without explicit statement of a logical necessity). The realization may bring various reactions: eagerness, ambivalence, dismay, sturdiness, turmoil, simple acceptance.

Knowledge is not something that is external and definite but something that each individual constructs according to his/her experience, background, etc.

7. Initial Commitment: First commitment(s) or affirmation(s). Acceptance of their origins in self's experience and choices, some intimations of implications.

Knowledge is the world view one has constructed from learning and experience, along with the ethical implications of this view, synthesized into a consistent philosophy.

8. Orientations in Implications of Commitment: Some implications of commitment realized: tensions between feelings of tentativeness and finality, expansion and narrowing, freedom and constraint, action and reflection. Prospect of (or even experience of) membership with authority in areas of Commitment (values, address to others, occupation, etc.) Identity in both content of Commitment and in personal style of address to Commitment.

Knowledge is a creative resolution between uncertainty and the need to act, which makes it a dynamic means of transaction between the self the environment, requiring both stability and flexibility.

9. Developing Commitment: Reassessment of commitments with new priorities. Commitments expended or remade in new terms as growth. Balances are developing in the tensions of qualitative polarities of style, especially alternation of reflection and action. Acceptance of changes of mood and outlook within continuity of identity. Sense of being "in" one's life.

Knowledge is the evolution of awareness, best expressed as ascending levels of consciousness, in which the individual must break through to new perspectives and discard those no longer useful.