

Abstract

This thesis describes an investigation into the ways in which learning using a multimedia application can be supported and enhanced by means of a co-operative student model of learner characteristics. The hypothesis investigated was that learning with multimedia requires the application of a student model and individual configuration in order to increase the quality of learning. The work consisted of a series of experiments performed to establish the effectiveness of the descriptors used within the student model, language and cognitive style, followed by a large scale study in the use of an individually configurable multimedia application.

In the first experiment, significant differences in performance were found for users having either full, or no additional language support where language skills were poor. In this experiment, users having full language support did better on the course than users with no additional support, when their language skills were poor. In the second experiment, significant differences in performance were found between learners at the extremes of the Verbaliser-Imager dimension when materials were presented in a form which either supported or did not support their preferred cognitive styles. Users were found to perform better when multimedia was presented in a form that matched their preferred cognitive style than when it was presented in a form that did not.

The final study involved the design, implementation and evaluation of an individually configurable multimedia learning application, based upon a co-operative student model of learners' characteristics. The quality of learning was shown to be improved by the use of the co-operative student model, and also to relate to the quality of the multimedia materials themselves, and to the management of the learning process.

The contribution of the work described in this thesis is therefore to demonstrate how the quality of learning provided by a multimedia application is improved by the use of a co-operative student model of learners' characteristics, and how an understanding of the characteristics of learners, tutors and learning environments is necessary in order to describe the complexity of the relationships that influence the quality of learning.

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Chapter 1

Introduction to the project

1.1 Introduction

“Computer-Assisted Learning (CAL) practices and Artificial Intelligence (AI) prototypes have always remained at a distance with few successful attempts to establish dialogues between the respective researchers and developers” (Hartley 1998).

One can understand the concerns of Hartley, since both CAL and AI have promised much, yet perhaps delivered less than expected. However, recent advances in the power of computers have seen corresponding developments in both areas, with the advent of interactive multimedia learning applications and Intelligent Tutoring Systems (ITS).

Multimedia is capable of providing a rich environment, which some people believe to be ideal for the delivery of effective learning. AI has been used to configure the presentation of information depending on the specific requirements of an individual user of an application. A model of user characteristics, a student model, is sometimes used to assist in configuring the presentation of information for an individual (Milne et al 1996). The term, 'student model' is used in this thesis

to mean the representation of characteristics of a student in a form which can be used within a computer application to configure the presentation of a multimedia course. This usage is referred to as a 'global description' of the student (Ohlson 1993), and may be contrasted with student models based upon students' knowledge in the domain, overlay models (Vassileva 1996). The project was undertaken in order to bring these two distinct methodologies together and to investigate the usefulness of the approach in the development of a learning application. The project presented here investigated the use of a student model to hold information that could be used to configure the presentation of learning for individuals on multimedia delivered courses. Thus, the overall aim of this project was to integrate the power and richness of multimedia with the potential for individual configuration afforded by AI, to produce a learning environment that could support learning effectively for the individual.

1.2 Hypothesis

The hypothesis investigated in the project can be summarised as follows:

The complex learning environment provided by computer delivered multimedia techniques requires the application of a student model and individual configuration in order to deliver its full potential in learning.

1.3 Objectives

In order to satisfy the overall aim of the project and to test the hypothesis above, the following objective was generated:

- 1 To produce a model of learners' characteristics that could be used to configure the presentation of learning for an individual.

This objective gave rise to two secondary aims:

- 1.1 To investigate the effect of language on performance in multimedia delivered courses.
- 1.2 To investigate the effect of cognitive style on performance in multimedia delivered courses.

It was necessary to create and evaluate individually configurable multimedia learning applications based on the student model to test the effectiveness of this in learning. The richness and complexity of the learning environment introduced difficulties in the evaluation of the effectiveness of the learning material. This led to a further objective.

- 2 To assess the effectiveness of a learning application in a differentiated, rich and complex environment.

1.4 Stages in the project

The project had the following stages:

- 1 A survey of the background theory and existing work in the area of learning as applied to multimedia, and the use of a student model.
- 2 Exploratory studies to establish methods for use in the project.
- 3 Experimental work to establish components of the student model
- 4 An extended study to apply the student model approach within a multimedia application and to investigate whether multimedia individually configured in this way, produced benefits in learning.

The exploratory studies performed in stage 2 of the project were important in understanding the development of the multimedia learning materials and also to establish the evaluation methods to be used in the project. Two experiments

were performed in stage 3, to show that the individual configuration of multimedia could improve performance in a multimedia learning application. The first was on the effect of language level on performance and the second was on the effect of cognitive style on performance in such an application. The results of these studies showed that, when each of these variables was taken in isolation, performance was improved when multimedia applications were configured for an individual's language skills and cognitive style. The final stage in testing the hypothesis involved constructing an application that could be configured individually, based on a learner's characteristics held in a student model. A large scale study was undertaken to investigate the use of the application with real learners. A range of qualitative and quantitative evaluation methods were employed to investigate the quality of the learning environment provided. An understanding of how a multimedia learning application based on a simple student model could be used to improve learning, was obtained. Evidence as to the effectiveness of the overall approach was also obtained.

Another important outcome from the project was the development of an understanding of the complex interactions that exist between learners, tutors and the learning or educational system in a multimedia learning environment. This is likely to provide a rich area for future research.

1.5 Outline of the structure of the thesis

Chapter 2 presents a review of the literature in the area of educational multimedia. This survey presents the current state of knowledge in several areas of study, including psychology, education, computer science and AI as they relate to this work. It is intended in the survey, to reflect the interdisciplinary nature of multimedia in the educational context. The survey first looks at how educational theories have been applied to teaching and learning from the early behaviourist ideas to the more recent theories of learning that have their roots in cognitive psychology. The application of computers to education is then described, from

early programmed instruction systems to modern multimedia applications. The features of multimedia applications as they relate to education are also described in the survey. Next, some of the important features in the design of multimedia systems are discussed. An important theme of the project is the individual configuration of multimedia learning systems. For this reason, issues related to the individual configuration of multimedia are described. Individual cognitive styles and learning styles are discussed along with examples of how these ideas have been used in learning applications in the past. The application of intelligent systems to learning are described. This relates to the concept of the 'student model', used to hold information about the characteristics of the individual learners using the multimedia learning systems.

Chapter 3 presents the results of exploratory studies which were undertaken to lay the foundations of the main sections of the project. Significant amounts of multimedia materials were developed within the project, for use in experiments reported in chapters 4 and 5 and for the large scale study reported in chapters 6, 7, 8 and 9. In order to develop this material, many assumptions had to be made related to the material's design, including pedagogical, usability, presentation and other issues. These assumptions were developed into a specification for the materials used in this project. Some assumptions were made, based very much on theoretical considerations identified in Chapter 2. Some features of the specification however were so central to the project that they needed to be tested directly. Chapter 3, therefore, describes two exploratory studies that were undertaken to look more deeply at the assumptions underlying the specification for the materials. Exploratory study 1 was carried out in order to develop an understanding of the pedagogical and related practical issues in developing multimedia learning materials. Exploratory study 2 was concerned with methods for the summative evaluation of multimedia learning materials for use later in the project.

Chapter 4 presents the first of the experimental investigations. The aim of the experimental work was to introduce and explore variables that were likely to be important in the configuration of learning for an individual learner. Experiment 1 described the effect of an individual's language skills on performance in a multimedia learning application. Three groups of learners undertook a food commodities multimedia course. Language support was configured differently for learners within these groups and the effect on their performance was measured and subjected to statistical analysis.

Chapter 5 presents a second experimental study. This study investigated the effect of individual learning style on performance in a multimedia learning application. Cognitive styles and learning styles influence the way people see the world at a fundamental level (Riding 1991a). This level, it has been argued, has its roots in our biological make up. Learners are constrained by biology to see the world in different ways. The experiment studied how learners classified as *Verbalisers* performed compared to those classified as *Imagers* in sections of a multimedia application that differed in the use of words and images. It was hoped to relate performance in these different sections with the cognitive style of the participants. Once again, results were subjected to statistical analysis

The next four chapters describe the final study in the project. This study was intended to investigate the usefulness of the individual configuration and student model approach developed in the project. Chapter 6 introduces this study. The objective of the final study was to develop, implement and evaluate a multimedia course based on a student model of learner characteristics. The student model was used in this application to configure presentation of the course according to each learner's individual characteristics. Chapter 6 introduces and justifies the methods used in the final study. The Grounded Theory approach used in the study relied upon a mixture of qualitative and quantitative methods. Reasons for using this method and why an experimental approach was not possible are

explained. The chapter also explains ideas behind the use of a co-operative student model in the study.

Chapter 7 describes the materials and methods used in the final study. This covers the design and development of the learning materials including how the student model was established and implemented and the structure of the materials and course developed. Stages in the implementation of the study are also described in this chapter. Chapter 7 also presents the evaluation methods employed in the study. The stages in the evaluation of the final study are described in the form of a Grounded Theory study. This includes the data collection methods used in the study.

Chapter 8 presents the results of the final study. Qualitative and quantitative evidence is described in this chapter. Chapter 9 discusses the results of the final study and attempts to relate these results to the theory to be grounded. Grounding the theory involves the development and presentation of a storyline or narrative which describes how the complex factors involved in understanding the research question are causally related. Evidence from a wide range of qualitative and quantitative sources is integrated in order to provide a solution to the problem of the evaluation of the effectiveness of the student model approach in learning with multimedia.

Chapter 10 discusses the project as a whole and draws together ideas from all sections of the project in order to evaluate the hypothesis presented earlier. The chapter assesses and discusses the significance of the work undertaken within this project with respect to some general issues regarding the application of multimedia in education. Ideas for the future direction of research in this area are also presented.

Chapter 2

Learning and computers: a review of the literature

2.1 Introduction

In this chapter, a survey of the literature related to the application of multimedia to learning is reported. The survey draws together work that has been undertaken in the disciplines of psychology, computer science and cognitive science that have led to current understanding in this area. In addition, attention is paid to the more aesthetic areas of screen design and media quality in so far as they relate to the development of multimedia learning applications. In the final section, ideas in AI are surveyed and their importance and potential in the individual configuration of multimedia learning applications is discussed.

Multimedia applications used in education and training are a relatively recent phenomenon. The development and use of multimedia has been influenced by many social and economic factors related to the enormous growth of computing in the world today. The roots of multimedia however have a relatively long history which stretches back to early applications of the computer in the 1950s and 1960s. Tannenbaum describes simple musical and graphical applications of

the computer in the 1950s although he considers the IBM 1500 computer, developed in the 1960s, to be the first true computer-based multimedia system (Tannenbaum 1998).

The history of the development of learning theories and applications is also relevant to the development and application of multimedia technology in education. These theories and their application to learning and training methods may be traced from the early days of psychological investigations at the turn of the last century. It is important to consider how the understanding of the underlying principles of learning and the development of computer technology have interacted in the development of multimedia in education. Multimedia offers great potential as a tool in learning. The object of this chapter is to survey the development of multimedia used in education and to look at issues related to its role.

The perception of quality of multimedia applications is highly complex and can be shown to be influenced by many factors. These include the personal characteristics of the user (for example prior skill, language level, individual learning style, motivation etc.), the type of learning application, the interaction between the user and the system, design issues relating to the media, the delivery of the media, the learning environment and pedagogical principles associated with learning taking place. This review aims to survey some of the current thinking on these and related issues.

2.2 Learning theories

Theories of learning have influenced the design of learning and training programs for many years and are therefore especially important to the development of computer based teaching, training and learning.

The mechanisms underlying learning development have been the subject of study since the end of the last century. Much research has taken place in the past where learning performance on tests has been used to understand or support theories of learning. It is also important that the design of learning programs and applications takes into consideration current ideas and principles of learning. An understanding of how learning takes place in individuals may be able to influence not only the design of applications, but also the design of authoring tools and the design of suitable evaluation procedures.

2.2.1 Behaviourism

Behaviourism is a branch of psychology that is concerned with the study of animal and human behaviour. It is also a philosophy of psychology that holds that observable behaviour is the only important object of investigation by psychologists. These ideas had a profound influence on the design and development of learning applications. Prior to the advent of Behaviourist ideas, the work of Wundt and James had been concerned with understanding the processes of consciousness, mainly by introspection (James 1890; 1893). Freud had concerned himself with the unconscious with the development of psychoanalytical techniques (Freud 1950).

Early scientific psychologists were involved with the application of scientific techniques to the study of behaviour (Cattell 1896). Practical application of the new science of psychology to education was undertaken by the Progressive school including the work of John Dewey (Dewey 1900), who introduced the notion of stimulus and response (Dewey 1896). Thorndyke (1911) established the principles of operant conditioning or learning, and reinforcement was linked to the satisfaction of biological drives (Hull 1943). Skinner developed the application of reinforcement in operant conditioning to learning in humans (Skinner 1953; Skinner 1954). Skinner's ideas have been used extensively in the

development of training programs in the 1950s and 1960s, often referred to as programmed learning (PL) or programmed instruction (PI).

An important feature of behaviourism was the notion of rewarding correct responses in order to establish stimulus-response (S-R) links. Branching programs of learning were devised to provide competence-based paths through training material. In behaviourism, appropriate learning behaviour is shaped by serially structured sequences that model, establish and reinforce the relevant associations in the mind of the learner. The main features of behaviourist theory applied to the design of training included the linking together of simple associations to produce more complex ones, prior definitions of objectives with explicit and measurable performance criteria, low error rate, use of feedback and the routing of a learner based on performance.

The use of feedback, important in behaviourism, has been investigated in learning programs. Hannafin and colleagues have shown that learning increased as the amount of performance feedback to learners increased (Hannafin et al 1986; Hannafin and Colamaio 1987). Remedial training systems were devised by Crowder which did not avoid error, but rather used it to identify potential remedies (Crowder 1960). This in some ways went against the behaviourist tradition which discouraged error, although behaviourist features were also present.

2.2.2 Limitations to Behaviourist psychology

Scepticism about behaviourism increased in the 1960s and 1970s and the idea was beginning to emerge based largely on experience and research findings that many aspects of learning could not be explained by the application of behaviourist theories of learning. Craik and Watkins (1973) showed that rote memorisation was not effective and Nelson (1976) showed that requesting people to learn rarely resulted in superior performance, suggesting that

processes at a deeper level than simple behaviour were probably involved. Some early objections to behaviourist principles are summarised by Postman who deals with philosophical, empirical and logical objections to the theory (Postman 1947). Others were showing that mnemonics and strategies that add meaning to material vastly improve learning (Sweeney and Bellezza 1982). It is now generally accepted that it is appropriate to apply some principles of behaviourism to some aspects of the delivery of learning. 'Overall there is now probably sufficient evidence to show that learning can be efficiently accomplished by the use of the behaviourist characteristics' (Atkins 1993). Although there may be the element of truth in Atkins' view, it was realised that there were probably better ways of delivering learning than those recommended by the Behaviourist school.

Learning relates to changes in the mental state of an individual. People learn when they understand concepts, integrate new ideas into what they already know or explain ideas to themselves and to others. These mental features of learning are difficult to conceive of in terms of behaviour alone. If one defines learning as changes in mental state, Behaviourism cannot explain much of what goes on in people's minds when they learn. The next section considers features of cognitive psychology that make them important in the design of learning. Cognitive psychology can provide useful insight into mental processes. Cognitive theories may be used in the structure and design of learning that is interesting and involves learners actively in the learning process. The human mind is involved in the learning process and a system that ignores mental aspects such as thought is unlikely to provide a full picture. The next section looks at later attempts at understanding how we learn that take into account the role of our minds in the process.

2.2.3 Cognitive psychology

The term 'cognitive' is applied to theories of information processing that are concerned with what happens in between the stimulus and the behavioural

response. They include weak theories of information processing and social constructivist theories (Atkins 1993). Meta-cognition, defined as awareness of ones' own learning, is important in the selection of learning strategies. Constructivist theories of learning see learning as the 'subjective construction of meaning from experience in specific contexts' (Somekh 1996). In such theories, according to Somekh, a teacher is a negotiator or facilitator of shared understandings and not merely a transmitter of knowledge in the form of facts or rules. Knowledge is not externally defined in such theories, but is something which is socially constructed, context specific and not consistent across time or groups of learners. This is in marked contrast to the earlier behaviourist principles.

According to cognitive theories, learners use active mental processes or strategies to search for understanding. In these strategies, perspectives and interpretations are used by learners to create learning individually (Patrick 1992). Much research took place to support this view of learning, for example it was shown that people's expectations affected what is learned and remembered (Bower et al 1979). Broadbent suggested that the information processing theories of learning ignored the influence of learner's strategies and tended to hide the flexibility of performance and the variety of resources which are used by learners in learning (Broadbent 1987). The goal of training, then, and the design of learning applications may involve ensuring that appropriate cognitive strategies exist for the development of learning in an individual.

Early cognitive theories of learning have been seen as candidates for application to the design of learning. Ohlson stresses the need to focus on promising solutions in cognitive theory when designing learning applications. Cognitive theory has the potential to impact on design in two different ways: by guiding the generation process towards best design candidates and by facilitating evaluation (Ohlson 1993). The specific application of cognitive learning theory to the development of instructional principles has been approached in several ways by

different authors. Some ideas and guidelines that have been used in the past are given below.

- Advanced organisers (Ausubel 1963; 1968; Reigeluth and Stein 1983)
- Cognitive conflict (Piaget 1985).
- Succession of representations (Bruner 1966a; 1966b)
- Goal hierarchies (Anderson et al 1990).

General methods or guidelines in which cognitive theories can be used in the design of learning have been suggested by several authors. For example some general characteristics of instructional design based on cognitive principles are given by Atkins. Orientation and advanced organisers at the start of the material are stressed. Atkins also emphasises the requirement for meta-cognitive devices such as advice, help facilities and suggestions. Other features include learner engagement with the material, exploration and discovery with learners moving between symbolic representation and real life. Hypothesis and, explanation building in safe learning environments and support for interaction between learner and expert is also important according to Atkins (1993).

Wild has looked at the relationship between mental models and computer models in learning. Wild looks at the ways in which children use spreadsheet applications to build their own conceptual models (Wild 1996). Mental models are described by Getner and Stevens as a means of explaining human understanding (Getner and Stevens 1983), and the 'mediating intervention between perception and action'. The mental processes that take place when people learn is important for Cummings, who discusses the relationship between task level (TL) and deeper discussion level (DL) interactions in Intelligent Educational Systems (IES). Cummings suggests that there is a need to focus research attention on the more complex and interesting DL interactions between learners and computers and less on the easier TL interactions (Cummings 1993).

Others have looked at how cognitive skills may be applied to different types of learning. For example, Schoenfeld (1985) identified four components of mathematical expertise. These are, 1) resources, 2) heuristics, 3) control and 4) beliefs or expectations as to what is required. The identification of the cognitive components of skills that are required in mathematics may be used to configure learning better within complex domains.

The development of meta-level skills are important in learning according to Collins and colleagues (Collins et al 1989). Meta-level skills in learning are those skills often described in terms of a learner being able to look down on his/her own learning, as if from above. The development of these skills is widely held to be important in constructivist theories of learning. Authors have looked at ways to support the development of meta-cognitive skills in learning. To this end, Park and Hannafin present 20 empirically derived guidelines they suggest be used in the application of constructivist theories of learning to the development of learning applications (Park and Hannafin 1993). The application of their guidelines in the development of learning applications is intended to support the development of meta-level skills.

Other methods of applying cognitive theory to the design of learning have emerged. Richards (1996) for example states that of the many models of learning that exist, few are applied to software design. The model of learning adopted by Richards is the 'spreading ripples' model of learning (Richards 1996). Four stages are identified in this model: wanting, doing, feedback and digesting. Richards identifies eight guidelines based on these stages intended to assist learning application developers. Other researchers have selected more complex theories upon which to base the design of learning. Fitzgerald and colleagues, for example, have applied the cognitive flexibility (CF) theory to the design and evaluation of multimedia applications. CF theory is a constructivist theory that emphasises real-world complexity and the ill-structuredness of learning (Fitzgerald et al 1997).

2.2.4 Limitations to Cognitive psychology

There have been suggestions that it is not straightforward to apply cognitive principles to the design of learning applications. Atkins, for example, suggests that learning application developers are more interested in cost-benefit analysis than pure questions of the application of cognition to learning (Atkins 1993). The historical split between behaviourism and cognitive approaches does not assist the development of learning materials according to Atkins. There is at present no single coherent model of learning to support the design of learning applications. For this reason then, it is not always possible in practice to make exclusive use of constructivist learning when designing learning applications. Often large sections of courses are based upon Skinnerian principles and are instructivist in their nature, for a variety of reasons. Applications of cognitive theories that support constructive learning are more difficult to devise, though more interesting.

Two key issues are identified by Somekh, for software developers:

- Deciding on the right balance of emphasis between the two kinds of learning (instructivist and constructivist).
- Devising computer-mediated experiences capable of supporting the second type (constructivist learning of concepts).

(Somekh 1996)

The widely held suggestion therefore that cognitive theory should have universal implications for design of CBI is only weakly supported by the evidence according to Ohlson (1993). Authoring systems might be built on a theory of design rather than learning and instruction theories according to Ohlson. This idea has appeal to designers since such theories are likely to be simpler and easier to understand

than theories of learning. Logan (1988) suggests that the choice of a learning theory in the design of training depends very much on the training situation.

Cognitive theories of learning emphasise involvement of the individual in the learning process. The power of modern computers facilitates the configuration of learning for specific individual characteristics of learners. Individualised learning might, then, be superimposed upon general structures derived from the general principles of cognitive learning theories. The potential of this approach will be described later in this chapter. In the next section the application of the computer to learning is surveyed.

2.3 Computer-Aided Learning

In this section, the development of the computer-aided learning is described. The design of computer-aided learning materials is complex and involves several stages, including authoring learning material and translating this for delivery on a computer. The general process has been described fully by Alessi and Trollip (1991). Once the course material to be delivered has been specified, the course structure determines the ways in which learning is presented and controls important features such as learner participation and interaction. The course structure and how it relates to underlying learning theory is an extremely important feature of learning material. Learning theories are difficult but important concepts in the design of learning and training materials. The process of creating a computer-based learning application involves selecting learning material and mapping structures, designs and presentations based upon a theory of learning and design to this material (Boyle 1997). Boyle refers to the mapping process as 'pedagogical structuring'.

The computer as a delivery mechanism for learning has been important for many years. The learning environments provided by early computer systems were not rich in today's terms, but in the context of their time were revolutionary. The

systems described below are referred to as 'training applications'. This is because the emphasis in their design was based very much on instructivist ideas about how teaching should take place, rather than constructivist ideas about learning. The early reliance on teaching or training using computers is emphasised by Patrick (1992), who gives four uses of computers in education, namely the provision of training, the development of training, the management of training and research into training. The terminology used for computers in training, though, is not straightforward and is used differently in the United States and the UK. A simple operational distinction between Computer-Assisted Learning (CAL), Computer-Assisted Instruction (CAI), Computer-Managed Learning (CML), Computer-Based Training (CBT) and Computer-Based Learning (CBL) is summarised by Staley (1995).

There are many examples of the early application of computers to the design of learning applications in the literature. Reports of the efficacy of such applications were mixed however. For example a review by Hartley looked at 112 studies in programmed instruction, a precursor to CAL (Hartley 1966). Hartley concluded that those undertaking programmed instruction took less time to complete the course than conventional training, had better post-test scores on average, but re-test scores were not significantly better. Hartley cautions that the studies he reviewed were often small scale.

CAI systems include simple drill-and-practice systems as well as more complex tutorial systems. Suppes and Morningstar describe applications of drill-and-practice systems in mathematics (Suppes and Morningstar 1969). Early applications of CAI include the PLATO (Programmed Logic for Automated Teaching Operations) system are described by Hurlock and Slough (1976). The TICCIT system (Time-shared Interactive Computer Controlled Information Television) was developed in the 1970s in America (Merrill 1988). Hartley stated that the completion rate of the TICCIT was 16% compared to 50% on conventional mathematics programs (Hartley 1985a).

McCann reports a remedial mathematics program using the PLATO system (McCann 1975). The use of feedback to reinforce students' performance was rated highly by students, though it did not significantly affect performance. The development of more 'intelligent' CAI tutorial systems to deliver training may be contrasted with drill-and-practice systems. Such systems often had complex rule procedures built in to make them more typical of students' interaction with humans than simple rote learning systems (Collins and Adams 1977). The key features of many such systems included flexible use with real-time decisions, branching and differentiated paths available to students depending on their performance in the program.

An early model for the design of CAI programs was developed by Cooley and Glaser based largely on Skinnerian principles. They suggested that: the goals of learning be specified in terms of observable student behaviour and that initial assessment of students' capabilities be undertaken. Educational alternatives suited to the students' initial capabilities could then be presented and assigned or selected. Performance monitoring is used to guide presentation and data for monitoring the system is stored (Cooley and Glaser 1969). The behaviourist influence in the above guidelines is readily apparent in what could be considered an early precursor to modern AI applications.

The evaluation of CAI applications has not proven to be straightforward. Suppes and Morningstar (1968) suggest that some of the superior results attributed to CAI systems may have been due to poor teacher preparation or delivery related to the conventional course being compared with the CAI system. This point is supported by Reeves (1991) who states that such comparisons may indeed be misguided. Benefits of CAI may stand for themselves and not require direct comparison with alternative methods of delivery. For example, CAI systems can be personalised and may attend to individual attributes of learners. Singer notes that mistakes are not 'penalised by scorn' and successes are positively reinforced

in CAI systems (Singer 1968). Tutors have more time to spend with students (Dossett and Hulvershorn 1983).

Fielden (1977) has looked at the cost-effectiveness of CBT, emphasising the subjectivity and complexity of comparisons. Costing criteria and measures of effectiveness of military CBT system evaluations have been criticised by Orlansky and String (1979). The Office of Technology Assessment in the USA states that up to three hundred hours are required to produce one hour of CBI, compared to thirty hours to produce one hour of classroom instruction (The Office of Technology Assessment 1990). The cost of CAI systems is expensive according to Goldstein (1993) although the costs are falling. Some learners prefer to be taught by conventional methods and not by machines (Pattern and Stermer 1969). This is less likely to be the case today as we become more accustomed to using computers according to Underwood (1994).

As the power of computers has increased, so has the sophistication of computer delivered learning. The integration of new technologies with three established educational technologies is described by De Diana and White (1994), who describe the information highway and the use of Computer-Supported Collaborative (or Co-operative) Work (CSCW), Computer-Based Learning (CBL) and Electronic Books (EBs). Barker (1990) describes the authoring of electronic books and presents a set of basic design paradigms to support their development.

Modern computers have enormous power, even when compared to the large mainframe computers used in the past. The potential for using these machines on the desktop or in the classroom to deliver learning is enormous. Multimedia computing is a fairly recent addition to the tools available for the delivery of learning. The use of interactive multimedia to provide realistic simulation, full-screen high-resolution colour graphics, sound, animation and video provides not

only great potential, but also additional challenges in the design of learning. In the following sections the application of multimedia to learning is described.

2.4 Multimedia in learning

Multimedia has been defined by several authors. Mathison (1991) and McAteer and Shaw (1994) agree that it implies the combination of databases, text, graphics, animation, sound, video and speech synthesis into interactive computer delivered applications. Mathison also provides definitions of specifications, standards, common terms and applications of multimedia in education. Gayenski (1992) provides a concise summary of common terms used in multimedia and shows the relationship between the media, bandwidth and multimedia applications. The concepts of hypermedia, hypertext and multimedia are explained by Rada (1996) who defines multimedia as 'synchronised media'. Hypertext is text with links and hypermedia is described as multimedia with links. In systems used for learning, interacting with the application may add an extra dimension to what is possible according to Rada.

The processing power of modern computers, coupled with its capability to present text, three dimensional images, animation and video is fuelling a revolution in the way we work and learn (Tannenbaum 1998). The phenomenon of the Internet is perhaps an early manifestation of this revolution and the exponential growth of this world-wide network perhaps indicates what will be possible for multimedia in the future. Gilder states that 'for the next 30 years, bandwidth is likely to be the fastest growing resource in the world' (Gilder 1997). The Internet is at present a poor medium for delivery of multimedia but the future will see multimedia applications delivered on new, fast broadband network platforms that may replace the traditional CD-ROM and analogue media, such as television and radio according to Gilder. Weiser (1991) suggests that virtual simulated worlds will be created that are predicted to be indistinguishable from reality. We will be able to '*occupy* these worlds and *live* immersed within them'

(Weiser 1991). Multimedia authoring tools will become common and augment the word processor allowing us to produce and distribute multimedia documents over networks and to interact within these environments. There are many commercial reasons driving the development of the necessary hardware and software required for such systems according to Gilder (1997).

Applications of multimedia technology today include business publicity and marketing applications, scientific analysis, presentations, the humanities, virtual reality applications, information retrieval and help systems, books and encyclopaedias, games and entertainment and adaptive systems for those with disability (Tannenbaum 1998; Barker 1993; 1996). Home use of multimedia systems is fast becoming popular according to Gillham and colleagues (1995). They conclude, based on interviews with a range of multimedia users, that aesthetics, levels of interactivity and information content are important factors in user satisfaction.

An important application of multimedia is in the delivery of learning. The use of multimedia in instruction has long been recognised as a possibility since early CBI applications described earlier. Tannenbaum states that its application to learning remains a major use of the genre today (Tannenbaum 1998). In recent times modern interactive multimedia and the possibility of open, flexible and resource-based learning is revolutionising education according to Kaplan (1997). Vast investment has taken place in colleges of Further Education (FE) and universities over the last ten years (Barker 1996a; Gray and Warrender 1995). Cresswell describes experiences of replacing a university science course for first year undergraduates with a multimedia alternative. Learners were supported by mentors for up to 30 minutes each week over the duration of the programme (Cresswell 1997). Reasons cited by Cresswell, for the move to a multimedia replacement course, included those of economy and efficiency. It appears that in the future, educational applications of multimedia in resource-based learning are certain to increase, if only for these reasons. Implementation of resource-based

learning however necessitates the provision of a rich set of basic resources for learning, including multimedia resources.

Ferry de Rijcke, deputy director of the Dutch Process Management Information and Communication Technology (ICT) for Education project, in his address to the Euro Education 98 conference, emphasised the need for commercial organisations to become increasingly involved in educational multimedia software production (de Rijcke 1998). Despite the vast investment made in Holland for the ICT for education project, commercial multimedia producers are reluctant to invest in materials production according to de Rijcke. This is a universal concern and is certainly not just restricted to educational multimedia in Holland. Commercial organisations fear that there will be insufficient returns to make the high development costs worthwhile. Similar concerns were expressed at the Euro Education 98 conference relating to Scandinavian, British and American software development.

Despite this concern, there are a range of products now available in the UK that are directly or indirectly related to the HE and FE market (IBM 1995a, 1995b; AK Vision 1996; Microsoft 1998). Boyle supports the suggestion that a variety of educational multimedia resources, varying in both type and quality are indeed becoming available (Boyle 1998). In the Further Education Funding Council (FEFC) report on the educational superhighway (FEFC 1996) it was recommended that commercial organisations become engaged in creating learning materials. This advice is being followed to some extent resulting in the formation of several commercial and educational partnerships. Issues as to availability, subject content, quality, customisability, relevance and pedagogical concerns though, have prevented universal uptake and use of these materials (Barker 1996a).

The lack of high quality commercially developed materials in the past has led to the Teaching and Learning Technology Programme (TLTP) in Higher Education

(HE) and the establishment of a National Multimedia Consortium in FE to create the materials necessary to implement resource based learning (Arnold et al 1994; Barker 1996a; McAteer and Shaw 1995). Universities have been assisted with the high development cost of multimedia development by government grants to encourage development within the TLTP project. In FE, where such grants were not available, development costs have been shared by collaboration as described by Barker (1997)

2.5 Media issues

It is not possible within this project, to survey all aspects of the important subject of designing and creating multimedia applications. The following section, therefore, briefly summarises research into the component media (text, image, video and sound) used in the design of multimedia learning applications.

2.5.1 Text

There has been much research on the organisation and layout of text in presentations. There are several reviews available, Hartley (1985b) and Wright (1977) cover early work in the area of textual presentation. Guidelines for the use of text are given by many authors, for example, Koelers et al (1981), Galitz (1989) and Cox and Walker (1993) have produced such guidelines. There is an assumption that pleasing layout of text will lead to efficient transfer of learning (Clarke 1992).

2.5.2 Images

Technical aspects of image display on computers are covered fully in several texts, for example Hearne and Baker (1986) and Foley and colleagues (1990). Duchastel and Waller looked at images and their effect on the understanding of

text in instructional materials (Duchastel and Waller 1979). Levie and Lentz (1982) looked at the presentation of images to support text. Bernard looked at the effectiveness of illustrations in text (Bernard 1990). Clarke suggests photographic quality images are better than line drawings for motivation (Clarke 1992). Molitor and colleagues (1989) identified uses of images including representation, organisation, interpretation, transformation and decoration, Petre argues that there are some types of information that are difficult to express graphically (Petre 1995).

2.5.3 Video and animation

Yagger (1993) describes standards for video and animation on computers. Details for video file formats used in multimedia are given by Andleigh and Thakrar (1995). Text animations can add interest but may disrupt learning (the National Council for Educational Technology (NCET 1994b). McAteer and Shaw (1995) state that movement alerts attention and survey the use of animation in learning applications. Allesandrini and Rigney (1981) have shown that learners performed better after presentation of an interactive simulation than after reading text alone

The use of CD-ROM for video is held by Staley to be an important factor in the increased use of video in computer applications (Staley 1995). The application of video in learning programmes has been described by several authors, for example, Wexley and Latham (1981), Allen (1985), Christel (1994), Chu and Schramm (1967), NCET (1994c)

2.5.4 Sound

Rosebush surveys the use of sounds in commercial CD-ROM based multimedia products, providing examples of software applications used in sound production and integration in multimedia (Rosebush 1992). McAteer and Shaw (1995) and

Cox and Walker (1993) present guidelines for the use of sound. There is evidence that multimodal presentation (i.e. the presentation of information in a form that makes use of more than one sense of perception) may increase the amount of information taken in (Broadbent 1958; Hartman 1961; Travers 1964).

Baggett studied the role of temporal overlap in the presentation of audio information (Baggett 1984). She found that the temporal order of the presentation of sound and film was important in recall of information in the presentation. When auditory components preceded visual components, much of the auditory component was lost. This was attributed to differential formation of dual media associations. Several authors have looked at the use of sound in learning (Barron and Atkins 1994; Barron and Kysilka 1993; Muraida and Spector 1992; Nugent 1982; Hartman 1961; Enerson and Tunney 1984; Alessi and Trollip 1991; Barton and Dwyer 1987). Kenworthy suggested that poor readers benefit from hearing text presented, providing sound and text correspond exactly (Kenworthy 1993). Jasper states that there are many contradictions in the research performed in this area, probably due to variable experimental designs and other related factors (Jasper 1991).

2.6 The design of multimedia for learning

The different types of learning theory and how these may be applied to the design of learning applications were discussed in previous sections. In this section, work on the design of multimedia learning applications is surveyed. Problems of size and scope of multimedia materials are described. These are compounded by the ability to hyperlink (i.e. to move freely from place to place within an application) which poses additional problems for developers and users alike.

A large amount of educational multimedia is created using presentation-based authoring tools. Boyle describes the use of some of these in an educational

context (Boyle 1997). The limitations of such tools are discussed by McIntyre (1993). Presentation-based tools take no account of the logical structure of the underlying plan of the author. Such packages have made it relatively simple to overcome technical limitations of multimedia authoring, but provide no support for developing underlying strategies or for creating effective designs. There are also problems of reusing, adapting and maintaining software developed with such tools. McIntyre suggests that a theory of authoring which describes the knowledge in courseware and underlying structures will lead to the development of systems with consistent internal structures, leading to consistent behaviour and more reusable code (McIntyre 1993).

The use of a knowledge-based approach to authoring leads to many more levels of structure, providing descriptions at a higher level than the presentation level according to Thuring and colleagues. Strategy is separated from the presentation modality and distinction made between teaching strategy and domain. Thus strategy may be re-applied in different domains. The use of libraries of examples will provide support for inexperienced developers, encouraging good practice and reducing development time (Thuring et al 1995).

To increase the readability of a hyperdocument, authors need to strengthen factors that support the construction of mental models (coherence) and weaken those that impede it (cognitive overhead). Small scale local coherence relates to understanding local meaning of words and phrases. Global coherence relates to understanding of several clauses, sentences, paragraphs, pages and chapters. Studies of linear text by van Dijk and Kintsch have shown that documents set out in a well-defined structure assist in establishing both types of coherence. Fragmentation should be avoided to increase global coherence. Providing means for structuring, overview and reducing fragmentation will increase the coherence of a hyperdocument (van Dijk and Kintsch 1983).

Cognitive overhead can result from maintaining several trails at once. Limited capacity of human information processing is the reason for cognitive overhead. Excess orientation, navigation and user-interface adjustment place added strain on the user leading to cognitive overhead. Orientation cues are necessary according to Khan (1995) in order to identify current position with respect to overall structure. It is also necessary to be able to reconstruct the path to the current position and to distinguish options for moving on from this position according to Khan.

There is a correlation between orientation and comprehension according to Dillon and colleagues. This has been interpreted to show that reader's mental model depends on aspects of content and spatial information (Dillon et al 1994). Aspects of navigation include direction, moves forward and back, up and down and distance, steps and jumps (Khan 1995). User-interface adjustment relates to re-sizing, moving, closing windows etc. Tiled windows have been shown to lead to higher accuracy and speed than cascaded windows in searching tasks (Bly and Rosenberg 1986).

Authors might increase cognitive coherence and reduce cognitive overhead by a range of initiatives, including the use of labelled links, indicating equivalence between information units. The visualisation of document structure is important, with the provision of clues as to current location, path to this location and possible paths onwards. The provision of navigation facilities and the use of stable screen layout with windows of fixed size and position all help reduce cognitive overhead.

2.7 The use of multimedia in learning

It is often assumed that multimedia is capable of providing rich learning environments that benefit learners (McAteer and Shaw 1995). Evidence for the effectiveness of multimedia in learning however is less common. Bagui states that multimedia is able to enrich student learning by providing access to a wide range of knowledge represented as text, graphics, audio and video (Bagui 1998). In addition to knowledge content and presentation, other reasons cited by Bagui include dual coding aspects of information processing theory, student control of learning direction and pace, chunking of information in short-term memory, interactivity, flexibility, motivational effects and better structure of instruction. Stoney and Oliver (1998) have shown that adult learners respond favourable to the interactive nature of multimedia, provided their eight principles influencing motivation are adhered to. These are, immersion, reflection, play and flow, collaboration, learner control, curiosity, fantasy and challenge. They were able to show that learning environments endowed with these characteristics were able to satisfy the affective needs of their learners. The inherent motivational aspects of multimedia, colour, movement and sound have been emphasised as an aid to learning (McAteer and Shaw, 1995).

For multimedia to have a significant impact on learning and be effective, multimedia learning applications need to be available in sufficient quantity and at high quality. They will also have to be accepted by educators if they are to be used effectively in learning programmes. There is an alternative perception by many workers in the field however, that the quality and effectiveness of multimedia learning applications is less than is often claimed by the enthusiasts.

The impact of Information Technology in general on educational practice is less than has been predicted, even after ten years of investment in research, support and training according to Crook (1997). Despite the claim that almost all teaching is *multimedia* (Schramm, 1977), teachers have in many cases been

slow to accept and adopt computer based interactive multimedia in their teaching, and this may be why it is not delivering all that it might (Laurillard et al 1993).

Possible reasons for this are many. Some applications simply reproduce existing paper-based material in multimedia format and ignore the need for intrinsic motivation (Stoney and Wild 1998). Interaction, it is claimed is an aid to learning, but is often about navigation and not directed to learning. Hall (1994) distinguishes between real interaction and simple button pressing. Interaction should be about engaging the learner in the learning process, but often it is superficial. This neither aids learning nor adds to the motivation of the learner according to Hall. Carswell and colleagues consider that all too often, pedagogy is overshadowed by system design considerations in the development of multimedia learning applications. Developers should distinguish between 'what is possible – system design and what is desirable – pedagogical considerations' (Carswell et al 1997).

The underlying assumptions of multimedia learning materials are that people learn more effectively when they are actively engaged in the process and interacting with the materials in some way. Exercising control over the learning process and employing several different senses or modalities leads to increased enjoyment and learning (Tannenbaum 1998). These pedagogical assumptions have been challenged by Tergan (1997) who questions the claim that structural features of hypermedia mimic the structure of the mind. Empirical evidence does not support this view according to Tergan. Other assumptions challenged by Tergan include the assumption that constructivist learning is supported by hypermedia *per se* and that the presentation of media in multiple modes assists learning (Tergan 1997). The general assumption of increased enjoyment and learning with multimedia has been referred to as 'technology led enthusiasm' by Tergan (1997).

Many of the assumptions made about the benefits of multimedia and learning remain to be proven according to Tannenbaum (1997). Najjar (1996) has undertaken a review of the literature underlying the assumption that multimedia helps people to learn. He concludes that redundant media may not always improve learning compared to monomedia, but that in some specific situations multimedia may be useful in helping people to learn. This includes 1) when it encourages the dual coding of information, 2) when media support one another and 3) when learners have low prior aptitude or knowledge in the domain.

There is clearly a great deal of contradictory opinion as to the benefits of multimedia in learning. Academic institutions are eager to implement resource-based learning for a variety of reasons, including cost-effectiveness, staff ratios and efficiency of learning. Tutors seem divided into two fairly distinct camps; those who see the benefits and those who see the dangers.

Multimedia and its effects on learning are poorly understood. The successful incorporation of technology into teaching and learning requires more than just a decision to do so according to Lee and Greenwood (1997). The selection of the appropriate technological solution should only take place once pedagogical issues have been resolved (Lee and Greenwood 1997). The technological possibilities are proceeding at a pace that outstrips the rate of our understanding of the pedagogical processes involved.

There is evidence however, that, despite the above reservations, technology in general and more specifically computer-based learning applications are of great benefit to students with learning difficulties and/or disability (LD&D). Technology can both restrain and facilitate development for persons with disabilities according to Brodtkin and Bjorck-Akesson. They state that a positive view of technology is that it offers new possibilities for persons with functional impairments to participate more fully (Brodtkin and Bjorck-Akesson 1995).

It is likely that multimedia applications will become increasingly important in delivering directed learning to such students. The use of specialist reading software by teachers has been studied by Sepehr and Harris. They found that although much of the support for students with reading problems was centred on 'drill-and-practice' software, other approaches were becoming increasingly important. Teachers often used framework or content free type applications for background and motivation to a lesser extent (Sepehr and Harris 1995). There is a need to evaluate the effectiveness of such systems in the delivery of learning.

Alonso and colleagues have explored the incorporation of computers into the teaching of deaf or hearing impaired children. The Mehida system, an intelligent multimedia system designed for this purpose is described by them. The Mehida system covers finger spelling, gestures or sign language, lip reading and voice communication (Alfonso et al 1995). They state that there are few intelligent tutoring systems (ITS) used for hearing-impaired children. Alonso and colleagues conclude that in the Mehida system, multimedia is not just the representation of information using multiple media, but that it also plays an important role in the formative process. The variety of ways in which the information reaches the pupil is seen as a decisive factor in the system's success.

The National Council for Educational Technology (NCET) have published a guide to software for learners with specific learning difficulties (NCET 1994a). The development of multimedia software for such specific need presents enormous challenges for its design, mode of use and evaluation. It does however promise great potential benefit for users.

2.8 The individual and learning with multimedia

The power of modern-day computers makes it possible to configure learning for each individual. The mental characteristics of an individual that relate to his/her learning include many features or variables, such as personality, intelligence, prior knowledge, attitude, motivation, language ability and cognitive style (Stoney & Wild 1998; Riding & Read 1996; Riding & Cheema 1991, Entwistle 1988; Jones et al 1997; Evans & Honour 1997). The process of configuring learning for individuals based on such information has its basis in AI. In this section some important individual characteristics are considered and methods for configuring learning based on them are discussed.

2.8.1 Learning styles and strategies

A learning style or strategy is a characteristic of an individual and is important in the development of learning applications for several reasons. In education today, open and flexible learning systems, often involving multimedia, are in common use (Barker 1996b). Within such systems, learning processes are often seen as being more important than teaching techniques. Learner control has been identified as being important in this process because it increases satisfaction (Miller 1990). The skills required to learn are seen as being central to these flexible methods and to the notion of learners taking responsibility for their own learning according to Miller. Learning styles are also seen in terms of egalitarian concepts, focusing more on individual strengths and less on weaknesses (Tennant 1988). There is also a great deal of evidence that failure to learn may often be a matter of style or strategy rather than intelligence or other characteristic of an individual (Riding 1996).

The application of constructivist theories of learning described previously may be able to focus on an individual's strengths and to use these to support learning more effectively. In addition it might be possible to look at how people apply their

own particular strategies to learning and learn from this how best to support learning in areas where a necessary strategy is absent.

Tennant describes cognitive styles as 'An individual's characteristic and consistent approach to organising and processing information' (Tennant 1988). Riding and Cheema (1991) have surveyed work on cognitive styles. They state that use of the terms 'cognitive style' and 'learning style' depend very much on the author, some using the terms interchangeably and others attempting to define each term. Riding and Cheema consider cognitive style to relate to the underlying theoretical and academic descriptions of an individual's biological makeup and learning style to relate to practical issues and descriptions of how individuals learn. Cognitive style is considered to be a 'bipolar dimension' while learning style involves many elements that are usually not 'either-or' extremes.

Several types of learning style have been studied in the past, Entwistle, for example, has identified three major categories of learner style, deep, surface and strategic (Entwistle 1988). Kolb (1984) has developed a system for describing preferred ways of receiving information. Two dimensions are described in Kolb's system, concrete-abstract and observational-testing. Four learning styles have been identified from these dimensions, Convergers (abstract/testing), Divergers (concrete/observational), Assimilators (abstract/observational) and Accommodators (concrete/testing). A complete learner is able to integrate the dialectical tension among the four modes.

Riding has described cognitive style families or dimensions as characteristics of an individual existing in two orthogonally related families. They are relatively stable or fixed in an individual, and are innate. Two families are described which correspond to Riding's dimensions.

- Wholist-Analytic Cognitive Style family. Wholists prefer learning in large chunks and may miss details, whereas analysts prefer to gather information in small pieces and may need support to see the whole scene.
- Verbaliser-Imager Cognitive Style family. Verbalisers think predominately in words whereas Imagers use pictures to encode knowledge.

An individual's cognitive style, it is argued, may be positioned somewhere along each of these two orthogonal dimensions.

Tennant (1988) has cited the following cognitive style families that have been used in the design of learning applications:

- Myers-Briggs type Indicators (Myers 1962)
- Learning Styles Inventory (Dunn 1975)
- Divergers-assimilator-converger-accomodator (Kolb 1977)
- Activist-reflective-theorist-pragmatic (Honey and Mumford 1986)
- Surface-deep (Entwistle 1988)

Riding and Read (1991) distinguish between learning style and learning strategy. Learning style is a relatively fixed characteristic of an individual and is seen to be independent of intelligence though this may affect performance in tasks. Learning strategies will also affect performance, but are learned in response to particular problems to provide specific solutions.

Little research has been done on hypermedia and learning styles according to Reed and colleagues (1997). The practical application of learning styles research to CBT has been investigated by De Diana and van der Heiden (1994) who have looked at electronic study books and individual modes of learning, or learning styles. The Style Initiating Module (SIM) is used at the beginning of the learning process to assess the individual learning style of a learner entering the

study book environment. Based on a set of neutrally stated multiple choice questions, De Diana and van der Heiden describe the test as setting a series of switches, according to the learner's preferred style. The output of the SIM could be used to determine the way materials in the electronic book are presented, according to a preferred learning style. The authors present options to relate learning styles and books, using the style initiating module within their application.

Ayersman (1993) provides a conceptual foundation for the development of hypermedia as an instructional tool for addressing individual learning style differences. He examines the relationship of hypermedia to the following learning theories: information processing, semantic networks, concept webbing/mapping, frames/scripting and schema theory from Piaget's work (Ayersman 1993). Ayersman found that performance on computer-based learning systems was related to an individual's learning style. There was a negative effect on learning when styles of presentation and learning were mismatched and a positive effect when they were matched.

In the context of this study, it will be important for the design and evaluation of multimedia learning applications to take into account the individual characteristics of learners. Individual measures of learners, coupled with measures of performance have been used in the development of knowledge-based, 'intelligent' learning systems that take over control of the learning process. Their development is described in the next section.

2.8.2 Student models

In this section, the background to student models is introduced. The concept of a student model is central to the work of this project, and relates to how information about a learner is held within a learning application, in order to configure presentation based on the characteristics of a learner. The term

'student model' has been used in two ways in the literature. It has been described as a representation of all information that could affect a student's learning (Muldner et al 1997). This might include prior skills and characteristics, such as language ability, learning style, intelligence etc. in a form that may be used in a computer learning application to configure the software specifically for an individual learner. A full and comprehensive student model is extremely complex and would be impossible to obtain according to Muldner and colleagues. Ohlsson (1993) describes this approach to student modelling as a 'global description' of the learner.

In contrast to a global description of a learner, the term has also been used as a special case of a user model which is concerned solely with representing the user's learning or knowledge within the domain (Milne et al, 1996). The application and classification of user models in general in the design and use of intelligent computer programmes has been surveyed by Benyon and Murray (1993). The student model in this sense, may also include user goals, prior knowledge and information about missing skills necessary to accomplish tasks within a domain (Brusilovsky and Schwartz 1997; Rich 1983; Wenger 1987). Brusilovsky states that many Intelligent Tutoring Systems (ITS) infer a model of a student's current understanding of the subject matter which is used to adapt instruction to students' needs (Brusilovsky, 1994). The 'student modelling loop' is described by Brusilovsky as the process of returning back performance scores to the student model for the purpose of adaptation.

Student models used to represent a learner's knowledge within a domain, the second type of student model, have been described as examples of 'overlay models' (Milne et al 1996; Milne et al 1997). The application of overlay user models has been described by Milne and colleagues. Such models contain information on learners' domain knowledge states and compare these to expert tutoring models and domain models (Milne et al 1996).

Intelligent help systems have also been used in the past to assist learners. Brueker (1990) has reviewed this area and states that the aim of such systems is to provide help to those using complex interfaces, such as large databases, multimedia and hypermedia applications. Barker and colleagues (1994) describe the application of neural networks and expert systems to the development of electronic performance support systems (EPSS). Expert systems are described as 'software tools containing domain expertise that can be used to solve problems within a particular subject area' (Barker et al 1994). The application of such ideas to educational systems has been surveyed by Brusilovsky (1996), who describes the use of adaptive hypermedia systems in a range of contexts, including Intelligent tutoring systems (ITS). He suggests that adaptive systems should be based on a user model and should adapt presentation of material for users according to information held in this model. Angelides lists four necessary conditions for developing a full ITS, namely, incorporation of student, domain and tutoring models in the system, explicit and direct links between related parts of the three models, hierarchical and non-hierarchical links included in the system and additional domain knowledge generated by the system (Angelides 1995). These requirements are seen as difficult to achieve by Angelides. Smith and Jagodzinski (1995) describe the application of a student model approach to the design of a multimedia learning environment. The model they describe is a domain knowledge model which calculates the best way to present knowledge to the learner. It adapts presentation according to performance by demonstrating solutions and offering scaffolding (i.e. support and help systems). Performance on the course determines exactly how material is presented and is an example of an overlay model.

Brusilovsky (1996) also sees automatic adaptive user modelling as being problematic. He sees two areas for uncertainty, namely in the creation of the student model and in the adaptive process according to Brusilokovsky (1996). Suni and Ross were able to show however that there were improvements in performance for some learners using an adaptive controlled hypermedia

application over those able to navigate freely (Suni and Ross 1997). This was especially true when questions were linked to animations, but not so when questions related to problem solving.

Collaborative or co-operative models have been described by Vassileva (1996) as one of the many ways that user models may be established, configured and/or applied. Collaborative methods are an alternative to fully automatic configuration of the presentation and involve user input into the system. Collaboration (user input) may take place at one or more of the three main stages in user modelling, at the data collection, application or presentation stage (Vassileva 1996). Collaborative student models are consistent with a constructivist approach to learning. Full automatic adaptive student models are more in line with an instructivist approach to learning.

2.9 Discussion

Educational multimedia is a complex technique that includes many specialist areas. These areas include the psychology of learning and perception and pedagogical considerations as to the structure of learning and courses and how these relate to individual characteristics of learners, including such issues as learning style, strategy and motivation. In addition there are important areas of screen design and layout that must be considered, involving the physical properties of the media, and users' perceptions of quality. The production, editing and assembly of the individual media is also relevant. Modern computer systems are important in the delivery of multimedia and new ideas in AI linked to hypertext and hypermedia will be important in the future. The creation of multimedia is not simply to do with the media, the pedagogy and the technology. It is also to do with the human systems that are needed to allow people to interact individually and together and with such systems. Understanding this is essential to the development of multimedia learning applications in the future.

In this survey the development of ideas about learning were discussed. Early instructivist ideas based on Behaviourism saw learners as part of a teaching system, designed to deliver a programme of instruction to learners. More recent constructivist ideas arising from Cognitive psychology, saw learners as individuals who needed to construct learning for themselves, situated in real contexts. It may be argued that in order to support learners as individuals, we require the application of computers to provide the richness and complexity needed. The survey therefore looked at the development of computer-assisted learning and the evolution of computer-based learning/teaching programmes from their early beginnings to the advent of modern multimedia systems. Some of the ideas about how multimedia could be used to provide learning environments were presented. Interaction was identified as an important feature of computer-delivered multimedia learning. Ideas relating to the design of interactive learning systems were described, including some of the limitations of large interactive systems and the need to relate underlying learning theory and the construction of mental models to the structure of the learning application.

In order to support individual learners in using multimedia learning applications, an understanding of the characteristics of learners is necessary. Individual learning styles were described as an important measure of individual learners. These, it is argued, may be used to obtain a better understanding of the learner profile and to assist in the construction of individualised learning environments. Several cognitive and learning style systems were presented. Simple applications of learning styles to computer-presented learning were also described.

The complexity of a multimedia learning environment, configurable for individuals, requires sophisticated management in order to base presentation on learners' characteristics. The application of AI to the delivery of learning was next described, as a system with the potential to do just this. The concept of a student model was therefore introduced, and the difference between overlay

models and models of user characteristics (global descriptors) was discussed. Another important distinction made was the difference between automatically adaptive modelling and a co-operative/collaborative modelling approach.

The future development of rich and complex multimedia learning systems that are configurable for individuals is a great challenge for the future. Our current understanding of how people learn suggests that such systems will need to be based on sound learning theory, consider learners as individuals with a set of individual characteristics and configure presentation based on this model of learners.

The evaluation of such complex systems raises many problems. For example it is difficult in large, complex, individually configurable systems with great numbers of pathways and presentation modes, to be able to evaluate systems fully. It is unlikely that any two users of a system ever experience the same system due to its inherent complexity. This is also true of expert evaluators, who may only assess a small part of a large system. These important problems will be approached in the remaining chapters. In the past, research centred on the effectiveness of the component media in the delivery of learning. Other research centred on comparison between the types of media, text and image for example, and attempts to show the effect on learning of these different media (Reeves 1993). Reeves has identified some problems with this type of approach.

In addition to the general problem of evaluating multimedia, the individual configuration of learning applications for individual users will pose many challenges for their evaluation. The evaluation of multimedia and hypermedia applications has been approached by many authors. For example Dix and colleagues have looked at usability issues (Dix et al 1993). Henderson and colleagues describe the application of four methods of evaluation (Henderson et al 1995). Laws and Barber describe video-based methods of evaluation (Laws and Barber 1995) and Yildiz and Atkins criticise the simplistic comparative

evaluations of the 1970s where the use of a new media is compared to traditional methods of learning delivery (Yildiz and Atkins 1993). Individual configuration of learning implies that individual methods of evaluation will be important in assessing the effectiveness of the application. This important issue will be discussed in chapter 6 of this thesis.

Chapter 3

Exploratory studies

3.1 Introduction

The purpose of this chapter is to present work undertaken in the form of exploratory studies prior to the main experimental work and full-scale study described in later chapters. Exploratory studies were performed in order to establish a framework upon which to base the development of the multimedia learning materials used in this project. Only two exploratory studies are reported here, though many more were carried out in order to develop ideas for use in the project.

Exploratory study 1 looked at the development and application of pedagogical and other principles for use in developing the multimedia learning applications used in the project. Many of the guidelines and principles used in multimedia development for the project were based upon theoretical considerations such as those discussed in the previous chapter. It was important to test the effectiveness of these ideas and to justify the many assumptions made in the development of the material for the project. Exploratory study 2 was concerned with the development and application of a range of evaluation methods used in the final project.

In summary, the exploratory studies were undertaken to achieve the following objectives:

Exploratory study 1

- To arrive at good design methods for multimedia material to be used in the studies.
- To test the many pedagogical assumptions underlying the multimedia material produced for the studies.
- To test models of implementation and delivery of multimedia courses in real situations.

Exploratory study 2

- To produce and test a range of formative and summative evaluation methods and tools for use in the studies.

Both exploratory studies were implemented in the form of relatively small-scale projects using expert evaluators and small groups of students. They were performed in learning centres in a college of FE. Exploratory study 1 was an extended study on four courses performed over a one year period. It was based on work done by mainstream students in an FE college using a range of software. Exploratory study 2 was based on an extension of one of the applications developed within exploratory study 1 and involved learners with learning difficulties and disabilities on the Horizon project (Barker et al, 1997a; 1997b).

3.2 Exploratory study 1: An evaluation of principles and guidelines used in the development of multimedia learning materials

3.2.1 Introduction to exploratory study 1

Four multimedia courses were developed in this exploratory study. These courses had several significant features which were important for later work. Firstly, they were centred around the use of tasks and questions, rather than the more traditional multimedia courses that delivered large amounts of information. Information was provided in the prototypes in a form mostly to support learner activities. Secondly, applications provided different routes through the course for individual learners, depending on tasks and question level being followed.

In the previous chapter, constructivist theories of learning were described as 'subjective construction of meaning from experience in specific contexts' (Somekh 1996). Participation in active learning tasks is seen to be important in such a constructivist view of learning (Grabinger et al 1997; Park and Hannafin 1993). Tasks provide a means of engaging students' attention, and users of computer-based instruction packages are therefore commonly required to interact with the material. Frequent decision points are important as are games and simulations in which the results of decisions can be immediately seen (Atkins 1993).

It has been suggested that the task of building computer models may provide direct support for the construction of mental models. Wild (1996), and Khan and Yip (1996) see tasks involving free exploration and self-directed learning as important for the testing of such models. Khan and Yip suggest that for maximum effectiveness, task-centred instruction should be situated in tasks

where knowledge is normally applied. The use of tasks to develop higher level cognitive skills in learning has been considered in the classroom by Felder and Brent (1994). Passive learning and an algorithmic approach to problem solving were cited among the reasons for high drop-out rates in science courses. In-class exercises investigated as an alternative approach included recall, stage setting and problem solving, and provide inspiration for the development of tasks for incorporation in multimedia learning packages. The use of questions also is important in developing good approaches to learning according to Felder and Brent (1994). Questions may range from simple multiple-choice selections testing recall of simple information, to tests of the organisation and structuring of complex ideas. Felder (1993) describes how questions can be used in a range of ways to motivate learners by providing interesting challenges.

On the basis of work such as that described above, it has been suggested that the appropriate use of tasks and questions in the design of learning applications is likely to be important in learning. It was considered important to test this assumption in the exploratory study and to investigate how it might be applied to a multimedia prototype. Many types of task could be used in the design of multimedia learning applications ranging from simple on-screen point-and-click activities to complex tasks involving groups of learners, taking place away from the computer. The importance of learner control and differential paths in interactive multimedia learning materials has been emphasised by Stoney and Oliver (1998). The ability of learners to construct their own paths through the material leads to increased motivation, engagement and supports the possibility of learners working at their own pace and level (Stoney and Oliver 1998). It was important to gain experience in the design and implementation of task based, differentiated learning materials.

3.2.2 Development of the materials

Multimedia learning applications were developed for this exploratory study using methods described by Barker and colleagues (1997c). The following materials were produced:

Catering studies:	6 NVQ units at foundation level (Horizon project)
Business studies:	4 NVQ units at level 2 (Horizon project)
Key skills:	1 unit for Application of Number level 1
English Law:	1 unit for GCSE Law.

These materials were created as interactive multimedia applications, based on a single template. An iterative rapid application development method was used (Rushby 1997; Preece 1994). Pedagogical features to be included in the template were agreed within development teams as described by Barker and colleagues (1997c). The template was based upon a simple hierarchical structure that allowed learners to navigate freely between areas of the courses. Simple navigation, orientation and location tools were provided based on the recommendation of Allinson and Hammond (1990). Each area of the course had information to be presented, tasks, questions and review screens. The intention of these was to engage and involve learners and also to be able to assess learner progress through the material. All navigational data and results of tasks and questions could be saved to file for individual learners.

3.2.2.1 Differentiation of materials

Materials were differentiated according to the level of task available and the type of questions presented. Tasks at different levels were defined in relation to Bloom's taxonomy of learning levels (Bloom 1956) in which the first three levels are:

- Level 1 - Knowledge: Fact recall with no real understanding
Level 2 - Comprehension: Ability to grasp the meaning of material
Level 3 – Application: Ability to use learned material in new situations.

Level 1 tasks and questions thus involve simple reproduction of the knowledge. Greater challenge was required to perform level two tasks. Comprehension of the material involving translation, interpretation and extrapolation was needed according to Bloom (1956). Level 3 tasks and questions involved the application of knowledge to practical situations. Tasks were implemented in several ways within the applications. Simple tasks involved pointing-and-clicking (or touching the screen), dragging-and-dropping and similar computer activities. More complex tasks often involve thinking time, group activities away from the computer and involvement of tutors and work supervisors. Tasks and questions for use in the applications were written by subject experts at the three different levels described above. Some examples of tasks and questions, at the three levels, that were used in the multimedia materials are given in Appendix 1.

3.2.3 Procedure

The applications were installed on computer networks for use in open access learning centres in the college using standard multimedia computers with sound and video capabilities. Subject groups and tutors were given standard brief introductory talks prior to first use of the system. Tutors were given some additional help with the use of the materials with their groups. This included the constructivist use of the materials, working in groups, motivating students, the use of tasks and questions and how to situate the use of materials in context. Help was also provided in configuring the materials for individuals, setting task and question levels for individual learners and accessing user data. In all, 36 learners took part in the exploratory study as shown in table 3.1 below.

Learners followed the materials under the direction of their tutors. Studies lasted from 1 or 2 weeks for the GCSE Law course, to 26 weeks for the Catering NVQ foundation level applications. At stages throughout the course and at the end of the courses, tutors and students were asked to complete questionnaires and to participate in group discussions with designers and sometimes tutors. Written reports and summaries were made of these meetings. Tutors also completed a short report on the use of the software with particular reference to the underlying pedagogy used in the development of the materials. Data was collected from user log files (see Appendix 5), throughout the duration of the exploratory study. This was used mostly to uncover problems in navigation and usability.

3.2.4 Results

It was not possible due to the nature and size of the projects, to test the significance of the statistical analysis presented here. This is because the studies were small scale and much of the evidence obtained was qualitative or anecdotal. Despite this, a great deal of useful information was obtained from the study which is discussed in the following sections under the headings, User satisfaction, Usability, Pedagogy, Performance and Tutor attitude to the material.

3.2.4.1 Users' satisfaction

In general the multimedia learning materials were rated highly by the students. This contrasted with ratings for other similar materials in use at the same time by the students. These materials were either developed commercially (i.e. bought in), or developed internally but not individually configurable. For example, learners undertaking the catering courses consistently rated the differentiated materials higher than the Essential Food Hygiene CD-ROM (Donaldson and Barker 1995a; 1995b) in use at the same time. This application was developed in similar ways to the NVQ material used in the exploratory study, but it was not individually configurable. Ten learners following the NVQ Food Hygiene option

were asked to place the applications and a traditional lecture in order of preference. All preferred the NVQ application to the Essential Food Hygiene application. The reason for this difference in preference was probably due to the fact that the NVQ application contained a far greater amount of task and question level differentiation. In most other respects the applications were very similar, though based on different courses. Nine out of ten learners preferred the NVQ Hygiene application to traditionally delivered lectures while only six out of ten preferred the Essential Food Hygiene CD-ROM to traditional lectures.

Most students reported in group discussions that they enjoyed working in groups and that exercises completed away from the computer were especially enjoyable. The requirement to report back to the tutor regularly, either as individuals or in groups was often mentioned as being a positive feature of the materials. Many students liked the flexible way the materials were used in study centres at a range of times. Some however saw this as a disadvantage and preferred a more structured approach to their learning. There are several possible reasons for this, including learners' previous experiences, their computer skills, the requirement for greater responsibility in self-directed learning, and motivational aspects of self-learning.

Some students reported that courses were too slow in some sections. It is thought that this was because sound had not been configured correctly for them (non-interruptible instead of interruptible). The need to configure applications at an optimal level rapidly became apparent in the exploratory study. User satisfaction relies not only on the configuration of learning, but also on the many other factors such as sound and graphics that make up the experience.

It was possible within the iterative prototyping method used, to test some of the guidelines presented in the previous chapter. This was done by simple expert evaluation and by asking users to rate screens and other features such as sound presentation in the prototypes. In this way, not only was the standard of learning

delivery improved, but also the aesthetic quality of the prototypes was improved. It was agreed at meetings of the project team that high aesthetic quality was to be aimed at, to ensure that applications were professional in their appearance. Early prototypes were rated poorly by learners, irrespective of their learning content, if their interface lacked good design quality.

The ability to repeat sections was often cited as important by learners, especially on the foundation level courses. Some learners reported following the material at one task/question level and negotiating with their tutor to follow the same material at a higher level. This was interesting in that it provided evidence that learners were engaging at a deep level with the material and were sufficiently motivated to take the work seriously. There was no opportunity for this kind of interaction between learner and tutor in the Essential Food Hygiene CD-ROM, which was essentially a stand-alone application. The differentiated paths through the application could also be thought of as providing a safe route for learners. Once learners had gained confidence at the lower task and question levels, they were able to explore greater challenges. This in itself might provide motivation for following the course. Interaction with the tutor was on many occasions reported as an important motivation. "Showing your teacher what you can do is better than a well done from the computer", according to one learner.

All learners were asked to complete a simple questionnaire which was developed for the exploratory study based on guidelines given by Oppenheim (1992). The results of the questionnaire are shown in table 3.1 below. The questionnaire used in the study is displayed in Appendix 2.

Table 3.1

Mean scores obtained in questionnaire on learners' attitudes to the four multimedia-delivered courses (where 1 = not very much and 5 = very much)

Question	Average score (Range 1-5)			
	Catering Number of students =12	Business Studies [*] Number of students =5	Application of Number of students =14	GCSE Law Number of students =5
How Interesting	3.8	3.2	4.1	3.9
How easy	4.1	3.0	3.8	4.2
How enjoyable	4.0	3.5	3.9	4.5
How much learned	3.6	2.9	4.1	4.0
How Useful were the following				
Working on your own	3.8	3.7	2.4	4.1
Working in pairs	3.6	3.2	3.9	4.1
Working in groups	3.9	2.6	4.0	3.1
Working with the tutor	3.2	2.1	3.9	3.7
Tests taken on the computer	2.9	2.8	3.2	3.7
Tests taken off the computer	3.1	4.3	2.8	4.3
Tasks done on the computer	3.4	3.8	3.5	3.5
Tasks done off the computer	3.5	4.1	3.5	4.2
Final Test or Examination	3.2	3.8	3.6	4.1
How Worried were you by:				
Using a computer	1.5	2.6	2.8	1
Using a mouse	2.4	2.9	2.5	1.4
Using headphones	1.5	2.1	1.9	1
Working in Learning Centre	2.9	3.6	3.8	3.4
Would you like to take another multimedia course in the future	% YES 83%	% YES 100%	% YES 86%	% YES 80%

Although the small size of the study limits the general applicability of these results, it is interesting to note that there are some differences between the

attitudes of learners in different groups. It appears from the results, that learners in all groups enjoyed following the courses and found them easy to follow. The lowest scores were obtained from the Business Studies group. Application of Number is traditionally a difficult course for many learners and it was surprising that it rated so highly as interesting, easy and enjoyable. The data on the usefulness of different ways of working and tasks and questions is complex and will be investigated in greater depth in the final study of this work. Group work was rated higher in Catering and Application of Number, and working alone was rated lowest in Application of Number. Most students did not report difficulty with using the computer hardware, though students in Business Studies, an area that uses Information Technology a great deal in their courses, had the least positive attitude to using the computers in learning. It is possible that students distinguish between using computers in their work and using computers for the delivery of their courses. It may be the need to use new computer-based learning methods that causes additional concern for some learners. It is interesting to note that the results of the questionnaire provide a slightly different view of learners' attitude than the group discussions. This may be due to the influence of peers, designers or tutors present at the meetings.

3.2.4.2 Usability

The usability of multimedia computer applications has been dealt with far less than other types of computer application according to Preece (1994), who presents many guidelines for creating usable interfaces for a range of applications. By the application of a user-centred approach to prototype development, many usability problems were identified in these exploratory studies. Designers were able to identify these problems, often working with experts as well as users. An interesting development was the reduction of unnecessary mouse clicks. Designers were often adding useless clicks in an attempt to make the software more interactive. Hall has emphasised the importance of providing real interaction rather than simple button pressing (Hall

1994). Extra button presses were quickly identified and removed and it became an important feature of the prototypes that mouse clicks were reduced to a minimum.

Other usability issues identified in the exploratory study included speed through sections of the material. Comparisons based on data from user log files were used to identify areas of difficulty and areas of the material not engaging the learners sufficiently. Learners would spend as little as thirty seconds on each screen in some areas of some applications. This was mostly independent of the amount of material presented. Often hyperlinks provided were not followed, either because they were missed or were of no interest to the learner. Screen design and application behaviour was changed to reflect this. Font sizes were increased and complex screens were broken down to reflect the amount of information that could be taken in during the thirty second 'window of opportunity'. Particular attention was paid to colour schemes and layout in order that information was not missed for this reason. Yellow on blue was considered the most 'usable' colour scheme by learning difficulty experts, though preferences were very varied. Hyperlinks were suitably emphasised by use of bright colours, sounds and boxes. Warnings were presented to users if important ones were still missed.

It is possible to take forward many lessons on usability from this exploratory study to future work. Most important was the need for user-centred design and the use of experts. By combining the two approaches, usability problems were solved effectively, quickly and efficiently.

3.2.4.3 Pedagogy

It was argued in the previous chapter that, in the design of learning materials, it is vitally important to consider the pedagogical structure of the material and to base this upon a theory of learning in order to provide a suitable structure for the

learning material. Pedagogical issues are important not only in the design of the multimedia materials, but also in how they were used. It was practically impossible to separate the design and use of materials in this exploratory study, so closely were they related. The need to understand design and use of learning materials was an important outcome of the study which influenced all subsequent design decisions in the full project. It was realised that the requirements for learning materials were complex due to the need for flexible use. This introduced ideas about how multimedia could be configured for individual learners in ways which would permit flexible and constructive use. These ideas were extremely important in the design of the learning materials and related ideas used in the rest of this project.

Another important outcome of the exploratory study, identified by several tutors, was the fact that pedagogy was actually being considered in learning in a practical sense. Most tutors reported that they liked the off-screen activities, though some did mention the additional load on their time that this imposed. The requirement for group working and the possibility of configuring the task and question levels were often mentioned as being good features by most. Some tutors did not use the materials in a constructivist way at all and left students very much to their own devices. Tutors did not always configure the materials for their students fully or take part in all activities. These tutors were less satisfied with the materials in general than those tutors taking an active part, or their students. These students seemed to enjoy the materials as much as those in other groups and still participated in the group and off-screen activities to a large extent.

The use of the materials in a vocational context was considered to be important by students and tutors alike. This was especially true of the key-skills materials where traditionally much teaching had been done by key-skills specialists. The ability to use materials and apply them in a vocational context was especially welcomed by those teaching in these areas. Constant links between the learning materials and activities taking place in the kitchen and store rooms were cited as

important by catering lecturers. The materials were described as task-based and assignment driven by one tutor who felt this was an improvement over most other materials available. An understanding of the need to base such curriculum materials as used in the exploratory study on real assessment with real rewards in real contexts was an important outcome for the future development of materials.

One important issue for the development of future applications used in the project was the use of scaffolding in the prototypes. Scaffolding is the provision of support and help, for learners, which may be removed when no longer required. It has been described by Stoney and Wild (1998) as a way of providing differential support for learners. They suggest that a range of cognitive levels be supported in applications to increase motivation. Scaffolding is an important way of supporting learning according to Somekh (1996) it can also be used to help extend a learner's knowledge. Scaffolding helps learners to pass their current level of achievement and enter their 'zone of proximal development' so that next time they do not require this additional support to achieve this level of understanding (Vygotsky, 1986).

Scaffolding was provided in the materials used in the exploratory studies in several ways, including hyper-linked support systems providing additional information in the form of text, images, diagrams and explanations. By far the most popular method of providing this scaffolding involved differential help paths. Materials were largely task-based as described above and only sufficient information to complete tasks was presented to learners in some cases. As learners progressed through the tasks, optional additional help was made available as needed. The level and sequence of this help was configurable in some places by the system, and in others by the tutor or the student. Tutors reported that this approach was more valuable than approaches used in other learning applications where student knowledge of the domain was assumed to be low or zero. In such applications information is often presented sequentially,

irrespective of learners' prior skills. The ability to configure the assumed domain level so that scaffolding could be provided at the appropriate level was important in the prototypes according to tutors. Students liked the possibility of trying tasks and questions and then being able to obtain more help if they needed it and to then try again. In this way tasks were usually completed.

The correct balance between an instructive Behaviourist approach and a constructive, Cognitive approach is an important feature of the design of learning materials. Within this exploratory study, a wealth of experience in designing a range of materials with a mixture of approaches was obtained.

3.2.4.4 Performance

Although a major objective of the exploratory study was to undertake a formative evaluation, it is relevant to consider how well learners performed on the final prototypes produced in the exploratory study. The evaluation of performance on a learning application is a complex issue, which is dealt with more fully in later chapters of this work. In its simplest form, It may be measured by test scores, but certainly involves more than just this according to Reeves (1992).

The following table provides a brief indication of performance on the courses covered in the exploratory study

Subject	Number of Students	Number of students Passing Objectives ¹	Average ² Scores on Questions (on-line)	Average ² Scores on Tasks (on-line)	Average ² Final test Score (off computer)
Catering:	12	12 (100%)	62%	53%	57%
Business studies:	6	5 (83%)	54%	58%	61%
Key skills: Application of Number	14	11 (79%)	59%	63%	52%
English Law:	5	5 (100%)	71%	69%	83%

Pass rates for the objectives covered were higher for all areas than for similar students following the same courses by traditional methods in the previous year. Mean pass rates obtained in the previous year for similar objectives are shown in table 3.3 below.

¹ 'Passing objectives' here relates to the objectives covered by the material in the study and not the final pass rate for the course.

² Standard deviations are not available for these data

<u>Table 3.3</u> <u>Performance on non-multimedia courses in</u> <u>the year prior to exploratory study</u>		
Subject	Number of Students	Number of Students Passing Objectives ²
Catering:	36	28 (78%)
Business studies:	56	45 (80%)
Key skills: Application of Number	124	74 (60%)
English Law:	15	12 (80%)

Comparison of the results for the Application of Number course are extremely interesting. The failure rate on this course was approximately 40% when delivered conventionally, yet 80% of learners achieved the objectives covered on the multimedia course. Final test scores were within the range of results generally obtained in the other subject areas, although on-line question and task scores appear to be higher than on standard presentations of courses for all subject areas except Business Studies, in the opinion of tutors involved in the courses. Staff in the Business Studies curriculum area expressed some concern as to using computer-delivered assessments. It is possible that on-line assessments were supported less well in this curriculum area than in some others. It was difficult to compare performance on specific tasks and questions on the exploratory study with previous years' exercises, as the formats were usually quite different. Differences in the number of students passing objectives

² 'Passing objectives' here also relates to the objectives covered by the material in the study.

between years could also be due to this factor. The importance of tutors' attitudes is discussed later in this chapter.

These results emphasise the importance of considering systems outside of the multimedia application itself when evaluating performance. Such external systems include the tutor, the learning environment, technical support and a vast array of other influences on learning that became apparent in the exploratory study. These issues are dealt with in greater depth in the final section of this project.

In general, students were successful in using the materials. Most students achieved as good as, or better than average marks and benefited from using the multimedia courses. By configuring tasks and questions at appropriate levels, improved test and task results were obtained it is argued. Understanding the need for configuration of tasks and questions and the requirement for tutor involvement in configuring the applications was a major outcome of the exploratory study and is discussed in the next section.

3.2.4.5 Tutors' attitudes

It has been suggested that one major impediment to the implementation of modern technology in education is the attitude of tutors (Fitzgerald et al 1997). Reasons for this fact range from feelings of threat, lack of involvement in the process, lack of technical support, lack of training and inadequate resources.

It was considered important to approach the issue of tutors' attitudes directly during the initial training period and also by involvement in the process. Teachers reported a feeling of sharing in the project, of being part of a larger support system, which gave them confidence in using the applications. Having experts available to help was also mentioned positively and the software

development team considered that this feature should be included at least initially in any new project.

By far the most often cited reason for positive attitude change towards the application in tutors was the amount and quality of student involvement in the tasks. The task-based approach was cited as being important in all but one course. Tutors also considered that their involvement in the whole process influenced their feelings to the applications. The necessity to involve tutors in the process was taken up by the design team as an essential feature to be included in all later studies. The need to develop and evaluate the effectiveness of high quality tasks and questions for the iterative prototyping methods used in the application design ensured that tutors were involved in all stages of the design process. This feature will be discussed more fully in the final section of this work.

Some teachers did not like setting the task and question levels too low as they considered this devalued the course. This was particularly evident in the Business Studies course, where tutors were especially careful not to lower course standards.

It was considered important to involve tutors as widely as possible in setting questions and configuring levels for their students.

3.2.5 Conclusion: Exploratory study 1

The exploratory study was extremely valuable in the development of the prototypes used throughout this project. Although the software development team had experience in the practical design of educational software, it was important to test out theories and guidelines from the literature. There were also many new ideas that had to be tested and their usefulness evaluated, especially in the areas of task and question design and differentiation. The major lessons learned from the exploratory study are set out below. All of these ideas were

important in the subsequent design of multimedia applications for use in the full project. Techniques were developed for the rapid identification of usability problems in software, based on expert and user-centred methods. Ideas regarding the balance between construction and instruction in multimedia modules were explored and models for achieving the correct balance investigated. The skills and tools necessary to create a range of tasks and at different levels were obtained. Models of how best to configure question and task level differentiation for an individual learner were generated and explored. The requirement to involve learners and tutors in human to human interaction emerged from the exploratory studies and became a design feature to be included in all future development work.

It was found that features needed to be included to support tutors in the individual configuration of learning materials, for example in the setting of task and question levels. Some tutors did not implement this fully with their students. It would be important in future work to make sure that all tutors were fully trained and shared the project objectives fully. Fitzgerald and colleagues (1997) found that best use of multimedia materials only occurred where materials were fully integrated into course construction and technical support was provided. It would be important in future work to consider the quality of the full learning systems.

The importance of tutor skills and support for tutors in teaching effectively with interactive multimedia technology is paramount and was a significant outcome of this study. Although the exploratory study was intended to be a formative evaluation of the prototypes, enough learners completed significant amounts of work using the finished prototype applications for some conclusions about the quality and usefulness of the courses to be drawn. The results of this were very encouraging.

3.3 Exploratory study 2: The development of methodologies for the evaluation of multimedia learning applications

3.3.1 Introduction to exploratory study 2

In the previous section, the development and formative evaluation of four multimedia courses was described. Evaluation, however, is important in all stages of the project life cycle according to Rushby (1997). Many authors have distinguished between summative and formative evaluation (Squires 1997; Rushby 1997; Thornton and Phillips 1997). Formative evaluation is carried out throughout the early stages in the development of the material. Summative evaluation relates to the evaluation of the final application and is important in assessing the effectiveness of materials after their implementation (Chanier 1996).

The aim of the second exploratory study was to produce and informally test a range of formative and summative evaluation methods and tools for use in the later studies.

3.3.2 Selection of material for the exploratory study

In order to develop a good range of suitable evaluation methods for use later in the project, it was necessary to undertake an extensive study over a considerable time span. This was because the nature of the material being developed for use in the project (highly differentiated and individually configurable), imposed considerable limitations on the types of materials that were suitable for use in the second exploratory study. It was not possible, for example, to use existing

multimedia material to test out evaluation methods for later use. An important implication of this limitation was that the second exploratory study would need to take place over a considerable period of time, in order to develop suitable materials, for staff and students to follow and evaluate the course and then to collect and analyse data.

Suitable materials were, however, being developed for use in the Horizon project. This project involved the development of multimedia learning materials for use by students with learning difficulty and disability and is described in detail by Barker and colleagues (1997a; 1997b). It was decided to base the exploratory study on multimedia materials developed for use in a Horizon catering NVQ Level 1 course for several reasons. The duration of the Horizon project was two years, which provided sufficient time to develop, implement and evaluate materials. Horizon materials were highly differentiated and individually configurable, in fact similar in many ways to the materials being developed for use in this project. This fact would allow a full range of evaluation methods to be developed that were suitable for application to the evaluation of differentiated and individually configurable materials in general. The special requirements of Horizon learners (students with learning difficulties) entailed a high level of tutor involvement and commitment, which was of great benefit in the development and testing of evaluation methods. Another important consideration was that the composition and membership of development teams was similar in both projects, allowing efficient transfer of skills and ideas between the exploratory study and the full project. Finally, Horizon learners would follow their course in similar ways, i.e., in college learning centres, using similar methods of following the course, and at similar levels, to learners who would be involved in this project. These factors taken together, suggested that the Horizon materials were ideally suited for use in the second exploratory study.

3.3.3 Specification of evaluation objectives

An important stage in designing an evaluation is the specification of evaluation objectives. These were specified early in the development cycle for the exploratory study in three areas. These were: the assessment of learning and pedagogy (Yildiz and Atkins 1993; Park and Hannafin 1993), usability (Dix et al 1994; Reeves and Harmon 1994) and user satisfaction (Squires and McDougall 1996; Reeves 1991). A set of detailed evaluation objectives in these areas was prepared and are shown in Appendix 3. It would be important within the framework of an exploratory study, to modify these objectives as necessary throughout the study.

3.3.4 Evaluation methods

Tools for the following methods of evaluation were developed in the exploratory study and an informal evaluation of the effectiveness of the methods was performed.

- Expert evaluation
- Analysis of logged data
- Questionnaire methods
- Interview methods
- Video methods

In the following section, the use of each of the evaluation methods is described.

3.3.4.1 Expert evaluation

Expert evaluation has been described by Perisco (1996), as a form of subjective evaluation performed on prototypes. Nielsen describes how small groups of expert evaluators were better than non-specialists at performing heuristic evaluation (Nielsen 1992). The use of expert evaluators is also described by

Catenazzi and colleagues (1997), who took the role of less experienced users to identify usability problems.

Expert evaluators also took part in the summative evaluation process in this exploratory study. Reeves and Harmon (1994) describe a method suitable for summative expert evaluation of materials. Based on these ideas, a tool was developed for expert summative evaluation of usability and pedagogical issues. The tool enables experts to rate features of the interface and pedagogical principles present or absent in the course. The tool is presented in Appendix 4.

3.3.4.2 Analysis of logged data

The use of automated data collection methods has been described by Henderson and colleagues (1995), who state that the technique is unobtrusive, inexpensive, accurate and reliable. However, Laws and Barber found it difficult to gain high-level insight from low-level data capture methods (Laws and Barber 1989).

In this exploratory study, a data logging system was developed for use on computer networks. Information recorded included login and logout times, times spent on each screen and navigation information. Information was recorded in a form whereby some idea of users' intentions could be inferred from the navigational data recorded. The data log file format developed for the system is given in Appendix 5.

Table 3.4 below presents data obtained from log files for two learners following the same catering course. User_12 has finished 2 sections in 12 minutes and answered 15 questions with 87% accuracy. User_14 failed to answer any questions and only entered one section of the course. The difference was in fact due to user_14 missing an important hyperlink, becoming lost, and spending the session time writing up notes. Analysis of the log file allowed the design team to correct the problem quickly.

Table 3.4

Summary information for two users from user log files

Details	User	
	User_12	User_14
Log in time	13.01	13.04
Section entered (1)	Microwaves 5.1	Microwaves 5.1
Section entered (2)	Microwaves 5.2	
Time section entered (1)	13.02	13.14
Time section finishes (1)	13.04	13.28
Time section entered (2)	13.06	-
Time section finishes (2)	13.13	-
Questions attempted	15	0
Questions correct	13 (87%)	0 (0%)
Screens completed	24	7
Total time (minutes)	12	24
Time spent per screen (minutes)	0.5	3.4
Log out time	13.14	13.29

Data logging produced large amounts of data cheaply, yet required expensive data analysis to be valuable. It was able to locate some usability problems very efficiently and also had the added benefit of recording learners' performance.

3.3.4.3 Questionnaire methods

The design and use of questionnaires has been described in many places in the literature. For example, Karat (1988) states that the method is inexpensive, fast and easy to process. However, Henderson and colleagues (1995) caution over

the use of questionnaire data taken in isolation. Questionnaires for the exploratory study were developed based on methods given by Oppenheim, (1992). Three types of questionnaire method were developed both for summative and formative evaluation of the Horizon material

- Paper-based questionnaires were developed from the evaluation guidelines. A five-point scale was used to record information about users' satisfaction, experiences and difficulties.
- Multimedia versions of questionnaires with sound support and simple graphical interface were developed.
- Group questionnaire methods as described by Oppenheim (1992) were used to overcome some of the limitations of the questionnaire method. Small groups of learners discussed and completed questionnaires together with their tutor at the end of sessions.

It was found that the questionnaire method was not useful in identifying specific problems in applications. Sometimes attributes rated on questionnaires, for example, did not exist in the application. Sound support was rated highly even when not used in one case. Sometimes learners clearly did not understand questions. The multimedia questionnaire was considered to be a good feature by expert evaluators and greatly simplified marking. Questionnaires were useful in assessing users' satisfaction however. The group questionnaire method was very useful, allowing exploration and more open questions. Users were able to share experiences about the application with tutors and often this led to new information about the application. Videos of group questionnaire sessions were found to be useful.

Questionnaires were helpful in finding out general attitudes but the individual nature of the Horizon material, the specific problems of learners and the small

sample size, made individually completed questionnaires less useful than other methods in this exploratory study. The group questionnaire method has potential for the future, possibly adapted for use in focus group studies. Questionnaires developed within the exploratory study were adapted for use in the full study and are shown in shown in Appendix 6.

3.3.4.4 Interview methods

Interviews were used only for formative evaluation in the exploratory study. They would be used for formative and summative evaluation in the full project. Cordingley (1989) describes the use of a semi-structured interview method that was adopted for this work. Structured components of the interview consisted of thirty-eight questions. Scripts were based closely on the evaluation objectives. The interview script used is shown in Appendix 7. Interviewers were fully briefed on the evaluation objectives and were present while learners were using the Horizon material. Participants could respond in any way to questions and were encouraged to explore issues. Interviews were recorded unobtrusively on video for later viewing.

The open-ended nature of the interview method used was important in locating problems that were missed by other methods. Interviews provided anecdotal information that was useful for developers in the early stages of the exploratory study. Video recording of sessions was useful as it recorded facial expressions and body gestures. Video recording did not affect subjects, who were keen to participate. Interview methods were expensive and required effort to set up and process data. They did however provide large amounts of useful information for developers.

3.3.4.5 Video methods

The video recording of students using multimedia applications was found to be important in both formative and summative evaluation. Extensive use was made

of video in later studies and a great deal of experience of using video methods was obtained in the exploratory study.

Video was used in two ways in the exploratory study. The first method was designed to record general information in loosely structured group video sessions. Up to six learners were recorded at each session. The camera operator followed instructions and recorded interesting features of sessions. For example, the features of the learning environment were recorded. Learners working in groups or with tutors was recorded. The intention was to understand how applications were being used.

More formally structured video sessions were carried out in the second method. These sessions closely followed a prepared script in order to record specific features of applications. For example, learners were asked to login, logout, navigate, answer questions, find information and perform tasks. Video scripts developed in the exploratory study for both methods are shown in Appendix 8.

The use of scripted video sessions was found to be efficient in the testing of problem areas identified by expert evaluation or other method. Group sessions were less useful for locating specific problems in the applications, but provided useful information on how courses were being followed, the learning environment, invested effort and motivation. Video methods were found to be expensive, yet were able to provide detailed and useful information and videos could be viewed repeatedly. The ability to view video repeatedly makes it more useful than simple observation (Laws and Barber 1989).

3.3.5 Conclusion of exploratory study 2

The exploratory study was important in that evaluation methods and tools were developed and implemented. These methods were to be used in the other areas of the project and it was important to understand, not only how to design tools for

the formative and summative evaluation of multimedia learning applications, but also how to perform evaluations effectively. Some important lessons were learned that would influence future evaluations.

It was the view of those involved in the second exploratory study that evaluation methods used in combination were found to be better than any single method at identifying problems. This view was expressed by members of the multimedia design team and by tutors involved in assessing the final multimedia applications. This appeared to be especially true when methods were combined with expert evaluation.

Summative evaluation centred on how useful the applications were in supporting learning and on features of the individual configuration of learning. All evaluation methods used were useful in assessing usability and users' satisfaction, it was however more difficult to assess the quality of learning. Indeed the more complex and differentiated the multimedia environment, the more difficult it became to construct tools to evaluate learning therein. It was agreed by the development team that expert evaluation was the most useful single method in the evaluation of the learning materials involved in the exploratory study. Tutors as experts were essential in this process and this method would be important in the full study. The quality of learning was best assessed by user-centred methods such as the group or multimedia questionnaire. Data logging was important, but only if it were possible to summarise the large amount of data into a suitable form for analysis.

Group questionnaires and interviews were also able to provide insight on the learning process, but only when experts were involved in the evaluation as discussion leaders. Squires and McDougall (1996) have stressed the need for evaluation to be situated in appropriate contexts. The evaluation of materials in vocational context was found to be important in this exploratory study and this principle was to be applied to future work.

Chapter 4

Investigation into the effect of language on performance in a multimedia learning application

4.1 Introduction

In this chapter, an investigation into how multimedia courseware was used to support students with differing language skills is described. The development of the multimedia systems and related supporting applications is also presented. The multimedia application developed was used in an experiment to see if language support was effective in improving performance in learners on catering courses in a college of FE. In the following sections, the investigation is described and the results presented. The potential of using language in the individual configuration of the presentation of multimedia learning applications is discussed in the concluding section of this chapter.

The aim of this study was to create a multimedia learning application that was configurable for learners in respect of the amount of language support given to

learners. It was intended to investigate how the provision of additional language support affected learning by groups of learners with differing levels of language abilities.

4.1.1 The importance of language in learning

When students start college courses, they come to the learning environment with a wide range of skills and characteristics that influence the way they learn and how they perform. These include their previous learning experiences, motivation, intelligence, learning strategies and cognitive style (Entwistle 1988). Perhaps the most important characteristic of an individual relating to learning is language. Language skills are vitally important in education and deficiencies in these areas are likely to lead to a deprived learning experience. It is often through the medium of language that people assimilate the most complex information and this means that language skills are vital to learners. In computer-delivered learning, interaction with a computer requires a sophisticated use of language. This is especially true in order to understand the complex written and spoken instructions necessary to follow a multimedia learning application.

Several authors have emphasised the need to support written text and the spoken word within computer applications. McAteer and Shaw (1995), for example, recommend that authors pay particular attention to the use of text in multimedia applications and emphasise the differences between presenting text on the computer screen and presenting text on a page. They recommend that sound and text be presented together to overcome the ephemeral nature of sound alone. Barron and Atkins (1994) suggest that sound presentation was important in learning through multimedia applications. They also suggest that learners with 'lower verbal ability' would be expected to benefit from textual and audio redundancy.

It is sometimes assumed that multimedia per se, with its use of image, video and animation, is able to compensate for deficiencies in learners' language skills. Shu (1988), for example argues for the inherent benefit of graphical representation. Petre (1995), however, challenges this view. Non-textual representations of information are not necessarily better at communicating information. Petre argues that there are some types of information that are difficult to express graphically or are open to many different interpretations. In multimedia learning applications, despite the use of other media, there is a high reliance on spoken and written language. Language is often more efficient at conveying meaning than the other media (Petre 1995).

The importance of text and spoken language in multimedia presentations leads to a high requirement for reading and listening skills in a learner. The user interface is also important in using multimedia applications. The use of language in the interface may also lead to problems in the usability of learning applications. Molich and Nielsen (1990) stress the need for clear simple language in the design of computer interfaces.

Language then, is important to students' use of computer-based learning applications. This is especially true for students in FE for several reasons. In many cases, the learners' first language is different from the language in which the course is delivered. There is also evidence that many learners in colleges, even when courses are delivered in their first language, have severe linguistic deficiencies when undertaking programs of learning (Barnsley 1996). In addition, the specialised vocabulary used in the delivery of some courses may be a problem for many learners. This is often the case with technical terms but may also apply across the whole range of language used. Linguistic styles may also be a cause of problems in learning.

Although the importance of language in learning has been emphasised by many workers, there are few reports of its application to multimedia learning

applications. For these reasons it was decided to undertake an experimental study on the effect of language on performance in a multimedia food studies application. In the next section the development of the applications and support tools used in the study is described.

4.2 Development of the software

Three pieces of software were developed for use in this investigation.

- 1 Computer-based tool to assess the language level of text used in the multimedia application (Language level tool).
- 2 Language testing tool to assess students' language skills
- 3 Catering commodities multimedia application that is able to provide differential language support for learners, including on-line assessment and questionnaire to assess users' impressions.

4.2.1 Language level tool for computer text

A computer program was developed to determine the language levels of texts used in the course. This application was designed to measure the Adult Literacy and Basic Skills Unit (ALBSU) SMOG levels (Vaughn 1995). SMOG levels are used as a standard within many FE colleges to classify learners' reading, writing and listening skills. The SMOG level is calculated from the length of sentences and the number of syllables in words used in a text. It has the advantage over other methods in that it is easy to calculate, reliable and commonly used in FE.

The language level tool was designed to analyse sections of text by reading files created by standard word processors and calculate the SMOG level of the text based on the number of syllables in a sample of text. Subject authors were able to use the tool to produce text at a range of SMOG levels, after undertaking a short training session. The language level tool for computer text is shown in Appendix 9.

The language level application described above was also used in the design of a subject/vocationally based language test for all students to take before the course. The development of the language testing tool is described in the next section.

4.2.2 Language testing tool for participants

The language test was based on closely related subject areas and consists of a simple listening and gapping test, based on the work of Vaughn (1995). Students could be classified according to whether they do well or poorly on this test. The language level of the tests was set to 16 on the ALBSU SMOG scale (Vaughn, 1995). The SMOG level 16 was selected as representing a convenient point on the SMOG scale upon which to base the test, after consultation with subject tutors and language support staff. The intention of the test was to identify learners with poor language skills and learners unable to perform well on this test set at level 16 on the SMOG scale were classified by language experts as having poor language skills.

The application tested simple listening and reading skills through text and sound presented on a computer. It comprised two parts, a listening comprehension test with multiple-choice questions to test understanding of spoken passages, and a word gap section where participants had to complete sentences by filling in blank spaces left in the text. The test was developed from materials within the catering subject area to make it relevant to users. The objective of the test was to divide learners broadly into two groups, those who required additional language support using a multimedia learning application and those whose language skills were sufficient to follow the application without additional support. The language testing tool for participants text is also shown in Appendix 9

The test developed followed closely existing language assessment and screening tests used routinely in the college. It was intended that reading and listening skills measured by the test were related directly to the skills required in the multimedia presentation.

4.2.3 Multimedia application

The application was developed by teams of subject specialists, multimedia specialists and language support specialists at Waltham Forest College. A method of iterative prototyping was used in order to develop the application. A description of the multimedia development process employed in the creation of the materials is given by Barker and colleagues (Barker et al 1997c). A final version of the application was completed approximately six months after the start of the development cycle.

The programme was designed to teach catering students about the catering commodity 'eggs'. As such it covered aspects of catering practical and theoretical work, including food science, food composition, food hygiene, storage, handling, nutrition, cookery and other related areas. The domain was selected to be relevant to as wide a range of students as possible. Catering specialists created a full specification for the application, which included text and narrative. After measuring the SMOG level of the language used in the initial text and narrative, the application was differentiated to provide extra language support in the following ways.

- 1 Alternative words were provided. Instead of a long difficult word, shorter, simpler words were used.
- 2 Sentences were made shorter. Long sentences were cut up and presented as several smaller ones.

The effect of 1 and 2 above was to create two versions of the text and narrative for the application, a high-level version at ALBSU SMOG level 18 and a lower level version at ALBSU SMOG level 14. These were used to create a prototype of the application that could be followed at either of the levels. It was intended that two pathways be provided through the prototype, a high-level language route, set at SMOG level 18 and a lower-level language route, set at SMOG level 14 that also had additional language support provided. The subject content covered in each pathway was identical.

In addition to reducing the SMOG level, additional language support was provided for the lower level pathway in the prototype by the following measures:

- 3 Sentences were made active rather than passive in the presentation with additional language support.
- 4 Additional hyper-linked glossaries and explanations were given where the language might be difficult, for example words like vitamin and protein were explained more in the extra support presentation.
- 5 Additional images and videos were available in the extra supported presentation. Only redundant information was provided in these additional files to make certain that no new information was provided.

The prototype was designed so that presentation could be varied within the application according to the values of configuration variables. The application was designed to read an individual configuration file for each user and set up sound and language properties accordingly.

- Language level = 0 High-level presentation, (SMOG level 18) with no extra language support
- Language level = 1 Low- level presentation, (SMOG level 14) with extra language support provided

Sound presentation was configurable within the application in a range of ways to allow flexible use. For this investigation, sound was set on, repeatable and interruptible.

It was intended within the experiment to present learners from three groups, 1) NVQ, 2) HND and 3) Staff, with multimedia materials configured at these two levels of additional language support. It was hoped then, to relate differences in performance on post-tests and re-tests in the domain to differences in the language skills of the participants and to the language level of the presentation they received. The experimental method is presented in the next section.

4.3 Experimental Method

4.3.1 Participants

Three groups of participants were involved in this experiment. Two groups of students, one following a Higher National Diploma (HND) and the other following a National Vocational Qualification (NVQ) level 2 in catering. A third group of non-catering lecturing staff also followed the course. These groups were selected for the trials for the following reasons.

- HND and NVQ students follow a similar core course in commodities as part of their normal curriculum.
- HND and NVQ students have different language skills and different requirements for additional language support.
- The staff group had no vocational or subject experience of catering, yet possessed a high level of language skills.

The following table shows characteristics of the participants involved in the trial. The language score for each group is shown in the table for comparison.

<u>Table 4.1</u>				
<u>Language scores and groups of participants in the study</u>				
Group	N	Mean age	Age Range	Mean % Language test score
NVQ	32	17.9	16-23	60
HND	32	19.3	17-35	81
Staff	20	29.3	23-47	93

Each group was divided randomly into two equal parts. This enabled participants in each group to be assigned to either of the presentation regimes as follows:

Presentation a without additional language support : language level 0

Presentation b with additional language support : language level 1

Details of sub-groupings and the language support presentations given are displayed in the table below.

Table 4.2

Additional language support, age and language test scores

Sub Group	Additional Language Support Given	N	Mean age	Age Range	Mean Language test score
NVQ a	None	16	18.3	16-23	62%
NVQ b	Full	16	17.4	16-22	57%
HND a	None	16	19.0	17-25	81%
HND b	Full	16	19.5	17-22	80%
Staff a	None	10	29.2	23-47	94%
Staff b	Full	10	29.8	23-45	92%

4.3.1.1 Expert users

Table 4.3 below presents the characteristics of a small group of catering staff (N=7), employed as expert users of the application prior to the main study, for the formative evaluation of the prototypes. They followed the course in the same way as other users, but were able to use the material in staff rooms as well as learning centres. Data was collected in the same way as for other users. All experts completed questionnaires and underwent short interviews. These results are discussed in the concluding section.

<u>Table 4.3</u>					
<u>Characteristics of expert users</u>					
Expert Group	Additional Language Support Given	N	Mean age	Age Range	Mean % Language test score
Catering Staff a	None	3	32.3	27-38	92
Catering Staff b	Full	4	39.3	29-47	94

4.3.2 Materials

The following materials were used in implementing the experiment.

- The multimedia course and language testing tool were implemented in TX Authoring software version 1.1 (BYG Systems Ltd Nottingham).
- The language level tool was written in Delphi 1.0 (Borland Ltd)
- Data collection tools were written in Visual Basic 3.0 (Microsoft Corporation)
- Statistical analysis was performed using SPSS version 7.5 for Windows and Microsoft Excel 5.0

The course was followed in College learning centres using standard multimedia PC computers with sound cards and CD-ROM drives, connected to a Novell 3.1 network.

4.3.3 Procedure

The application was installed on computer networks for use in open access learning centres in the college. All participants were volunteers and relatively experienced computer users. Participants were assigned randomly to groups as shown in the tables above. Participants were required to log in to a computer network and to the application in order to use the systems, to ensure security and to enable efficient data collection methods to be employed. All test results, configuration information and data logging files were saved to and read from central file servers. Participant groups were given a standard brief introductory talk prior to first use of the system. This was scripted to ensure a standard presentation of the introduction was given to all groups. All participants were given a user manual during the induction session, explaining how to follow the course in detail and how to operate the software. Immediately after induction, at the same session, participants were given the language test, followed by a subject pre-test, in order to measure prior knowledge of the subject area. The pre-test involved participants answering 30 multiple-choice questions about the subject content of the course material, presented on the computer in multimedia format.

Users then followed the course over a period of one week in open access computer areas (some expert staff users followed the course over longer periods, generally in their own rooms). Students were supervised all the time they used the application and all tests were taken under exam conditions. The level of additional help provided by tutors was small and usually related to using the application rather than subject information. Once the course had been completed, a multimedia post-test and user-evaluation was taken by all participants. The post-test consisted of 30 multiple choice questions about the subject content of the course material, presented on the computer in multimedia format. Differences between pre-test and post-test scores were intended to provide a measure of any learning taking place on the course. The user

evaluation consisted of a set of 30 questions delivered on the computer in multimedia format. The evaluation measured how interesting the course material was perceived to be by users, and identified any areas of difficulty within the course. There were also questions designed to measure the users' computer experience and familiarity with the use of multimedia hardware.

Two weeks later a supervised re-test was taken in multimedia format, delivered on a computer. The post-test and re-test were identical in format to the pre-test described above, except that the questions were different. All results were saved securely and anonymously on a computer network. An extensive data log file was created for each participant throughout the course. This held information about navigation and time spent in each section of the course. Performance in on-line questions and tasks was also recorded in this file.

In summary, the method had the following stages:

- Initial language assessment test presentation.
- Initial subject pre-test presentation.
- User configuration file created.
- Course followed with prescribed language support.
- Post-test presentation.
- Evaluation of the application by users.
- Re-test presentation two weeks after finishing the course.
- Data collected and analyzed.

Examples of the language test, pre-test, post-test, re-test, user evaluation and expert user interview questions described above are shown in Appendix 10.

4.4 Results

In this section, results obtained in the investigation and their statistical analysis are presented. Table 4.4 below presents the pre-test, post-test and re-test scores for groups following the commodities multimedia course. Results of the user evaluation questionnaire are also presented.

Table 4.4

Mean Pre-test, post-test and re-test and user evaluation scores
for participants following the multimedia course

(Standard deviations are shown in brackets)

<u>Group</u>	<u>N</u>	<u>Pre-Test</u>	<u>Post-Test</u>	<u>Re-Test</u>	<u>Evaluation</u>
Possible score		30	30	30	5
NVQ a	16	11.13 (3.4)	14.44 (4.5)	12.5 (3.3)	3.25
NVQ b	16	12.13 (3.7)	18.56 (3.0)	14.38 (3.5)	3.68
HND a	16	15.81 (2.7)	21.44 (3.7)	18.25 (3.5)	3.32
HND b	16	16.06 (3.3)	19.94 (4.1)	17.69 (3.5)	3.10
Staff a	10	14.50 (3.6)	20.3 (3.6)	17.1 (3.2)	3.20
Staff b	10	16.60 (3.4)	22.6 (2.1)	18.5 (3.9)	3.10

The following table 4.5 shows pre-test, post-test re-test and user evaluation results for expert users who followed the commodities course. No significant differences were found between the mean pre-test, post-test and re-test scores. The importance of expert user results is discussed in the concluding section.

<u>Table 4.5</u>					
<u>Mean¹ pre-test, post-test and re-test and user evaluation scores for expert users who followed the multimedia course</u>					
Possible score	N	Pre-Test (30)	Post-Test (30)	Re-Test (30)	Evaluation. (5)
<u>Group</u>					
Catering Staff a	3	25.00	26.67	27.00	3.20
Catering Staff b	4	25.57	26.67	26.67	3.63

4.4.1 Statistical Analysis

Inspection of table 4.4, mean pre-test, post-test and re-test and user evaluation scores for participants following the catering commodities multimedia course shows that there were differences in the mean scores obtained. This section presents the results of statistical analyses performed on the data.

4.4.1.1 Tests of assumptions

The ANOVA used in the data analysis assumes that the observed covariance matrices of the dependent variables are equal across groups. Box's Test of Equality of Covariance Matrices was employed to test the null hypothesis that

¹ Standard deviations are not available for these data

they were equal. The null hypothesis was accepted, based on an observed value of $p > 0.05$ (0.85)

Mauchly's test was employed to test the sphericity of the data within groups which is also an assumption for the appropriate use of an ANOVA. The observed value of $p > 0.05$ (0.98) meant that the null hypothesis could be accepted and sphericity of data assumed.

4.4.1.2 Analysis of variance (ANOVA)

The means of the TRIALS variable (pre-test score, re-test score and post-test score) were subjected to a repeated measures ANOVA. Table 4.6 below shows the results of this analysis.

Table 4.6					
<u>Tests of Within Subject Effects</u>					
<u>Results of repeated measures ANOVA performed on data from table 4.4</u>					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
TRIALS	1087.727	2	543.864	74.74	0.000
TRIALS x GROUP	10.452	4	2.613	0.359	0.837
TRIALS x LANGUAGE LEVEL	32.177	2	16.088	2.211	0.113
TRIALS x GROUP x LANGUAGE LEVEL	14.818	4	3.704	0.729	0.729
Error (TRIALS)	1135.175	156			

Table 4.6 shows a significant difference between the means of the TRIALS variable ($p < 0.001$). There were significant differences between the mean scores obtained in pre-test, post-test and re-test.

Between subject effects were also investigated for the TRIALS variable and the results of this analysis are presented in table 4.7 below.

<u>Table 4.7</u>					
<u>Tests of Between Subject Effects</u>					
<u>Results of repeated measures ANOVA performed on data from table 4.4</u>					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	67519.376	1	67519.3	3010.4	0.000
GROUP	1135.176	2	567.588	25.306	0.000
LANGUAGE LEVEL	158.167	1	158.167	7.052	0.010
GROUP x LANGUAGE LEVEL	38.347	2	19.173	0.855	0.429
Error	1749.438	78	22.429		

Examination of table 4.7 shows that there were significant between subject effects for the GROUP and LANGUAGE LEVEL variables.

It was not possible from the ANOVA performed to identify where the significant differences were located. Post hoc comparisons were therefore performed using Tukey's test in order to investigate the group means. Results of the post hoc comparisons are shown in table 4.8 below. This presents the significance of differences in the performance on pre-test, re-test and post-test for the three groups in the investigation. Significant differences at the 0.05 level are indicated by the presence of a '**' in the column.

Table 4.8								
Post hoc pair-wise differences in the means for the data presented in table 4.4								
** in a column indicates a significant difference at p<0.05								
Trial	Group	Language support Condition	1	2	3	4	5	6
Pre-Test			NVQ a	NVQ b	HND a	HND b	Staff a	Staff b
	NVQa	None			*	*		*
	NVQb	Full			*	*		*
	HNDa	None	*	*				
	HNDb	Full	*	*				
	Staffa	None						
Post-Test	Staffb	Full	*	*				
	NVQa	None		*	*	*	*	*
	NVQb	Full	*					
	HNDa	None	*					
	HNDb	Full	*					
	Staffa	None	*					
Re-Test	Staffb	Full	*					
	NVQa	None			*	*	*	*
	NVQb	Full				*		*
	HNDa	None	*					
	HNDb	Full	*	*				
	Staffa	None	*					
Staffb	Full	*	*					

Tukey's test indicated that there were significant differences between the performance of individual groups on pre-test, re-test and post-tests under different language level conditions. There were significant differences ($p < 0.05$) in pre-test scores between the NVQ and HND groups. This was likely to be due to different abilities, experience and prior knowledge. There were no differences ($p > 0.05$) between the HND supported and non-supported or NVQ supported and non-supported groups on performance in the pre-test or re-test. Staff groups performed better than the NVQ groups on all tests ($p < 0.05$), but no differently from the HND groups with one exception.

The most important difference found was in the re-test results. There were no differences between Staff and HND supported and non-supported groups ($p > 0.05$), yet there was a significant difference between NVQ supported and non-supported groups ($p < 0.05$). The NVQ group receiving additional support and lower level language presentation performed significantly better on the re-test than the NVQ group at the higher language level with no support. This suggests that the provision of additional language support was most effective in the NVQ learners. These learners scored lowest on the language tests and therefore were able to benefit most from the additional support provided. There was no significant difference ($p > 0.05$) between the language skills of the two NVQ groups, or in their pre-test scores. Differences in post-test scores then were most likely to be due to the additional language support provided.

All participants undertook an evaluation of the package in the form of a multimedia presented questionnaire. Table 4.4 shows that groups with the supported presentation (presentation b) on average scored the package higher than those with the unsupported presentation. This difference was greatest between the NVQ groups, those with additional support scoring it higher than those without the benefit of this ($p < 0.05$). Although there was no significant difference between the evaluation scores in other groups ($p > 0.05$), all groups with additional language support scored lower than those without. This might

suggest that the provision of additional language support may cause some level of de-motivation of learners with good language skills.

It may therefore be important to tailor the language level of the presentation closely to the language level of learners. In this way learners with poor language skills are likely to benefit from the additional language help available and perform better. Learners with good language skills, who were shown not to benefit from additional language support, may prefer a language presentation at their ability level.

The results of the expert users group suggest that there is no difference in pre-test, post-test and re-test scores when taken by subject experts. The small numbers of participants however prevent the use of statistical tests. There was no suggestion of any differences due to the language support provided in the presentation. The main reason for employing a group of expert users in the study was to make certain that the application was acceptable to vocational and subject experts and to identify any areas of possible difficulty for learners. To this end, all experts underwent a short semi-structured interview designed to locate problems, based on Neilson's guidelines for heuristic evaluation (Neilson 1992). The procedures used in this expert evaluation have been described by Barker et al (1997a) (see Appendix 11 for an example of the interview used in the expert evaluation).

Evaluation scores in this study were in general relatively high which suggests that expert users were reasonably satisfied with the content and presentation of their vocational and subject areas. The expert group with additional language support evaluated the application higher on average than the group with no additional language help. This was contrary to what was expected based on the results of HND and non-expert staff evaluations. It is likely to be due to the small numbers of expert users employed in this trial.

4.5 Discussion

Although vision is probably our most important sense there is evidence that application of senses other than vision to learning can increase the amount of information people take in (Broadbent 1958; Hartman 1961; Travers 1964). The use of sound has been shown to add to a learning presentation, not only in terms of content and information presentation effects, but it may add audio cues and interest to the application as with music and sound effects (McAteer and Shaw 1995). In addition there has been some research into the use of sound to assist learners with learning difficulties and disabilities and poor readers (NCET 1994a). The use of sound in these cases has been suggested to offer benefits when language skills are poor. This is in full accordance with the results of our study where additional language support was shown to benefit learners with the poorest reading and listening skills.

The use of sound for learners with poor language skills is an important feature of multimedia and is able to make up for some deficiencies in the learning experience. Barron and Atkins identified several important features in the use of sound in learning applications (Barron and Atkins 1994). In their study they looked at whether redundancy between audio and textual information affected learning. They found that there were significant differences between pre-test and post-test scores for all conditions, demonstrating learning had taken place, but were unable to show any differences between groups with audio-based presentation and text-based presentation.

Barron and Atkins reported that negative comments from learners included the feeling that the audio was too slow. This was prevented in our application by allowing the participant to configure sound as much as possible for themselves.

The gain in performance on the multimedia application was highest in the experiment described here where the learners with the greatest need for support

were able to obtain it. Indeed Alessi and Trollip found that presenting text with full narration actually impeded learning (Alessi and Trollip 1991). Although we did not find that learning was impeded by the provision of additional language support, it is important to consider these findings. It is possible that the provision of unnecessary additional language support might be a distraction to learning, though this was not supported in the experiment reported here. This could easily be ascribed for example to the effects of the de-motivation of the learner. There are implications in these results for the configuration of multimedia learning materials. When learners have high-level language skills, the provision of additional language support is not likely to be effective in improving performance on a multimedia course. When learners have language deficiencies, then, it is of benefit to learners to provide additional support and to present language at the appropriate level.

Meskill (1996), suggests that the control of the rate of language presentation in multimedia applications allows the retention of language chunks in short-term memory. This could in itself be important in improvement in performance in learning when listening skills are limiting. Meskill emphasised the potential of multimedia in language learning and sees listening as a skill integral to overall communicative competence. Co-ordinated visual, aural and textual information employed in multimedia can provide clues to the meaning of the written and aural text according to Meskill. The results of the investigation reported here indicate that the presentation of information at the appropriate language level assists in this process.

Barton and Dwyer report that participants with high verbal skills do not benefit from the addition of audio information in learning applications. They do suggest however, that participants with lower verbal skills might benefit from textual/audio redundancy in learning applications (Barton and Dwyer 1987). Kenworthy supports this view, suggesting that poor readers benefit from hearing text presented (Kenworthy 1993). There was a need for text presented to match

audio exactly if audio was used as additional language (Kenworthy 1993). This may be an aid to poor readers by identifying unfamiliar words. As a compromise, Kenworthy suggested that audio be made optional. It is also important to allow users to repeat sound passages. Kenworthy suggests that poor readers may want to pause the audio to study an unfamiliar word.

Riding and Vincent (1980) were able to show with groups of school children, when sound was presented slowly and in close proximity to the information to be learned that it was most effective in assisting recall of information (tested immediately afterwards). When sound was presented at a fast rate or separated in time from the information, it was less effective in assisting recall (Riding and Vincent, 1980). Shih and Alessi (1996) found no significant difference in learning between multimedia presentations with text, voice alone and text presented with voice. There was a marked preference however for text and voice presented together (Shih and Alessi 1996).

Work by Barron and Kysilka has shown that there was no significant difference when students were tested for immediate recall between a text based program and a combination text/audio program (Barron and Kysilka 1993). The text-based program required significantly less delivery time than the text/audio program. This result suggests that the language skills of the university level learners was reasonably high, since they were able to read faster than the presentation speed of the application. Where language skills are high, then learners are unlikely to benefit from the provision of additional language support. They are also less likely to be penalised if such support is not provided. Jasper suggests that there are many contradictions when research performed in this area is compared. This is likely to be due to many factors according to Jasper (1991). The results reported here suggest that the language skills of a learner are an important factor in performance on multimedia learning applications.

An important objective of the project as a whole was to produce a model of learners' characteristics that could be used to configure learning for an individual. This objective gave rise to a sub-objective which was to investigate the effect of language on performance in multimedia delivered courses. The results of the study reported here indicate that any model of learners' characteristics used to configure multimedia would benefit from the inclusion of language skills. How language skills were used in a model of learners' characteristics to configure learning is described in later chapters.

In the next chapter, an investigation of how an individual's cognitive style influences performance in multimedia delivered courses is reported, and its potential as a candidate for inclusion in the model of learners' characteristics is assessed.

Chapter 5

Investigation into the effect of cognitive style on performance in a multimedia learning application

5.1 Introduction

It has been argued that, despite the advent of new technology in education, there are some learners who are not benefiting from its application (Jones et al 1997). This is especially true of multimedia, where, despite the richness of the environment and the interactive nature of applications, it often does not fulfil its potential as a deliverer of learning. In the previous chapter the effect of language on performance in a multimedia learning application was investigated in order to understand possible reasons for this situation.

In this chapter, the importance of a learner's individual cognitive style in learning in multimedia applications is assessed. The development of a multimedia learning application capable of presenting information either in a format that matches a learner's cognitive style, or in a format that does not match cognitive

style is described and the findings are discussed. In chapter 1 of this thesis, it was stated that it was an objective to develop a model of learners' characteristics that could be used to configure learning for an individual. In the final section of this chapter, the potential of cognitive style for use in the configuration of learning is assessed.

5.1.1 Cognitive style and learning styles

The concept of cognitive style has been described as an underlying personal characteristic that is able to explain many of the features of the way people learn. Cognitive style, learning style and conceptual style are related terms which refer to an '*individual's characteristic and consistent approach to organising and processing information*' (Tennant 1988). For the purposes of this chapter, the term *learning style* is used to mean the same as *cognitive style*, according to Tennant's definition given above. Closely related to learning style, is the notion of learning strategy. Riding and Read distinguish between learning style and learning strategy. Learning style is a relatively fixed characteristic of an individual and is seen to be independent of intelligence though it will be likely to affect performance in a range of tasks. Learning strategies will also affect performance, but are learned and provide specific solutions to problems of acquiring knowledge (Riding and Read 1996).

5.1.2 The dimensions of learning styles

Learning styles originated from the work of Witkins who discovered a difference in people's perceptual judgement (Witkins, 1950). Some participants could accurately align a rod to the vertical in a tilted frame, classified as field independent, whilst others tended to align the rod to the frame irrespective of orientation, classified as field dependent. This difference was later found to

reflect large differences in people's cognitive styles, and to correlate to different psychological and personal characteristics.

Several different types of cognitive style have been suggested since Witkin's initial work on field dependence/field independence (Witkins 1950). Kolb and Fry have suggested four dimensions or types of learning style, based upon their experiential learning system, the Learning Styles Inventory (LSI) (Kolb and Fry 1975). Although there is little direct evidence for Kolb's dimensions, the converger, diverger, assimilator and accomodator suggested by them are seen as a useful framework in understanding how people learn (Tennant 1988). Recent studies by Yahya (1998), however, using factor analysis on Kolb's original data, has provided direct evidence for the application of Kolb's LSI. Other learning styles that have been shown to be important in learning include Surface - Deep (Pask 1976; Entwistle 1981) and Serialist-Holist (Biggs 1978). Tennant considers these styles to be reflections of Witkins' original field dependence/field independence system (Tennant 1988), reflecting underlying physical structures in the individual. Another cognitive style that has been identified by Riding is Wholist/Analyst and this is the focus of the experiment because of the way it is hypothesised to relate to learning.

5.1.3 Wholist/Analyst – Verbaliser /Imager system

Riding has described two bipolar dimensions of cognitive style. These are Wholist – Analyst (WA) and Verbaliser – Imager (VI) (Riding 1996). A simple computer-based test, the Cognitive Style Analysis (CSA), has been developed that is able to classify learners according to their position on the WA and VI dimensions (Riding 1991b).

Riding's WA dimension describes whether individuals process information in wholes or parts Riding (1996). The VI dimension classifies whether individuals represent information during thinking in words or pictures. The two styles or

dimensions are independent of each other, so that the position of an individual on one scale does not influence his/her position on the other. Wholists tend to see the whole of a picture and appreciate the whole of the context in one go. They have difficulty in appreciating the parts however. Analysts are capable of seeing the details of a situation, but may have difficulty in appreciating how parts relate together. Verbalisers tend to organise thinking as associations of words and Imagers think and handle mental information in the form of pictures. This will influence the mode of presentation they prefer and the type of task they find easy. Riding also relates the focus of Verbaliser and Imagers' activity as internal for Imagers and external for Verbalisers (Riding 1991a).

Riding and colleagues have related the WAVI cognitive styles to learning processes. For example, Riding and Sadler-Smith (1992) were able to show that the effectiveness of a learning package presented in text or image format could be related to learning style. There was a significant interaction between the application presentation style and learning style when pre-test and post-test scores were compared (Riding and Sadler-Smith 1992). Riding and Watts (1997) studied the effect of cognitive style on the preferred formats of learning materials. They found that Imagers were more likely to select picture-based presentations than text-based ones. Verbalisers were more likely to choose text based presentations (Riding and Watts 1997). Other work has shown that performance in different presentation modes closely matches learning style. In text plus picture presentations, Imagers performed better than Verbalisers. When text was presented without pictures, Verbalisers performed better than Imagers (Douglas and Riding 1993).

5.1.4 Implications for the design of courseware

The ideas inherent in the study of learning styles are important in constructivist ideas about how people learn. In the past, Computer-Based Training (CBT) courses were concerned primarily about teaching or instruction. Constructivist

ideas centre on how individuals construct knowledge for themselves. In constructivist learning, an individual's learning style is seen as central to the learning process. It has been suggested that it is possible to improve learning by paying attention to learning style when designing learning applications (Riding 1996; Entwistle 1981). Clarke (1993) used Pask's serialist and holist styles around which to base a CAL application. A simple assessment of learning style, using a single question is reported by Clarke. The richness of multimedia and the high quality visual content it may contain make it a prime candidate for delivering learning configured in a way appropriate to individual cognitive styles.

Riding's WAVI system has great potential for use in the design of multimedia applications for the following reasons.

- The VI dimension relates directly to multimedia presentation formats which facilitates production of differentiated material according to cognitive style.
- There is evidence (presented earlier) that the WA-VI dimensions have a significant influence on learning.
- Riding has developed a computer-based test that measures learning style directly: the Cognitive Styles Analysis (CSA) Riding (1991a).

The aim of the experiment presented in this chapter, was to investigate how learners' performance on a multimedia course was influenced by their cognitive style. Learners' individual cognitive styles were assessed along the VI dimension, using Riding's CSA test. In the experiment undertaken here, information was presented to learners in different sections of the multimedia course in a format that either matched their individual cognitive style, or in a format that did not. In this way, all learners experienced learning in both matched and unmatched formats. Performance in sections where information matched an individual's cognitive style (supported areas), was then compared to performance

in sections of the course where it did not (non-supported areas). In the concluding section of this chapter, differences in the potential of cognitive style as a candidate for the individual configuration of learning through multimedia is discussed.

5.2 Method

In the following paragraphs, the design and implementation of the experiment is described.

5.2.1 Design of the application

The multimedia application used in the investigation was developed using an iterative prototyping procedure as described by Barker et al (1997c). The programme delivered an English Language comprehension skills course based on material already in use in a FE college basic language skills workshop. In the application, participants were presented stories based on simple situations commonly encountered in everyday life. These situations were presented in two ways, either verbally, i.e. as text with supporting sound (spoken narrative), or as a series of images. Each situation was designed so that scenarios could be presented in both text and image formats. It was intended to present stories to participants in a format that either matched (supported) their preferred cognitive style, or in a format that did not match their cognitive style (not supported). A procedure was included within the application, to enable automatic random selection of the presentation format for each situation, at run-time.

The materials themselves were designed so that each short sequence of text and associated sound-track contained the same information as a single image. A situation, such as changing a library book, could therefore be viewed as a set of sixteen images in sequence or as a text-based story containing sixteen short

statements. The language level of the application was set to 14 on the Adult Literacy and Basic Skills Unit (ALBSU) SMOG scale as described by Vaughn (1995). This level was selected since it represented a suitable language level for the students who would be using the application, based on advice from language experts.

A set of questions about the story were presented directly after the presentation and in the same format as the presentation, i.e. either as images or text. A multimedia language screening test based on the work of Vaughn (1995) and a multimedia tool to measure participants' evaluation of the quality of the application were integrated into the application. The development of these tools is described in chapter 4 of this work.

Examples of the questions used in the application and details of the scenarios are shown in Appendix 12.

5.2.2 Participants

Participants were volunteer learners recruited from basic skills support and learning centres at Waltham Forest College, a college of FE. All reported being experienced computer users. All participants had English as their first language and had scored greater than 60 percent on the multimedia delivered language screening test, so that reading and listening skills would not limit performance in text/sound based areas of the course. No participants reported being colour blind. Participants were taken from a wide range of subject and vocational areas. This was decided after the results of an exploratory study suggested that participants from single curriculum areas might lack sufficient range along the WA and VI dimensions to allow the study to take place. The following table summarises characteristics of the participants.

Table 5.1

Characteristics of participants undertaking the learning styles and multimedia experiment

Number (n)	Male To Female M/F	Age range	Average age	Wholist Analyst (WA) Range	Verbaliser Imager (VI) Range	Mean language test score %
51	1.43	16-21	19.3	0.67-1.8	0.72-1.87	78.2%

5.2.3 Experimental method

Participants were given detailed scripted instructions in how to follow the multimedia course and associated tasks by a trained supervisor. Participants completed the course in a single session at their own pace and were fully supervised at all times. The experiment took place in computer learning centres on high specification multimedia computers connected to Novell 3.1 networks, using CD-ROM based software. Headphones were provided for all participants to exclude external noise. Suitably lit, quiet rooms were used for the study and participants were asked to adjust chairs and monitors for maximum comfort prior to following the course material.

After logging in to the application with a unique password, participants were instructed to complete the language screening test, followed immediately by Riding's computer-based CSA test (Riding 1991a). Participants then followed the multimedia course. This presented five scenarios or stories, each consisting of sixteen sections. Stories were presented either as verbal presentations using text and sound or as image-based presentations using pictures only. The design of

the application was described in the last section. A random number system was used to assign four of the five presentations for the participant, two as verbal and two as image-based presentations. The fifth and final presentation mode was selected by the participant as either verbal or image format according to their preference. Subject experts reported that verbal, text-based presentations were similar in content and difficulty level to image-based presentations.

After each section had been completed by a participant, a set of questions was presented to a participant based on the section just followed which he/she answered by selecting options presented on screen with a mouse pointer.

In summary all participants received two verbal presentations and, two image-based presentations selected by the computer, and a final presentation, the format of which they had to select themselves.

All answers to questions and other data were saved securely to network file servers for later analysis. Immediately after the application participants were required to complete a multimedia questionnaire to record their assessment of the application's quality. Participants could take a break at any time during the experiment, but only at the end of completed sections of the course. The complete procedure took between 1.5 and 3 hours.

The multimedia questionnaire used in the investigation is shown in Appendix 13.

5.2.4 Materials

The following materials were used in implementing the experiment.

- The multimedia course, language testing tool and multimedia questionnaire were implemented in TX Authoring software version 1.1 (BYG Systems Ltd Nottingham). The subject content of the course and the corresponding

questions were developed by an English language subject expert working at Waltham Forest College, in conjunction with a team multimedia software developers from the same college. This team developed the courseware based upon a specification provided for them by the project manager. Materials were subjected to formative evaluation by multimedia and subject experts, who rated them highly. An example of text-based and image-based sections of the course and sample questions developed in this way are shown in Appendix 12. The language testing tool and multimedia questionnaire were developed using methods described in chapter 4 of this work.

- Data collection and analysis tools were written in Visual Basic 3.0 (Microsoft Corporation).
- Statistical analysis was performed using SPSS version 7.5 for Windows and Microsoft Excel 5.0.

5.3 Results

The experiment involved 51 participants. The characteristics of participants are shown in table 5.1. In the first set of analyses, participants were classified into three groups by dividing them equally along VI dimension, according to their scores (Riding 1991b), producing 17 Verbalisers, 17 Bi-modal and 17 Imagers. Bi-modals are described by Riding (1991a) as possessing skills characteristic of both Verbaliser and Imager cognitive styles and are sometimes excluded from analyses (Kwok and Jones 1995). Initially they were included in this analysis to see if significant effects occurred even when they were included. Table 5.2 shows the mean scores obtained by each of the groups in verbal and image sections of the course.

Table 5.2

Mean scores obtained on the courses by groups characterised as Verbaliser Bi-modal and Imager (standard deviations are shown in brackets)

Group	N	Mean VI score	Mean Score in Verbal sections	Mean Score in Image sections	Mean Score in Choice Section
Verbaliser	17	0.87	66.9 (15.6)	61.3 (12.6)	65.1 (17.9)
Bi-modal	17	1.27	64.9 (18.1)	63.1 (17.8)	71.8 (19.5)
Imager	17	1.60	61.0 (16.7)	64.6 (17.6)	63.2 (17.9)

Table 5.3 below presents scores obtained by Verbalisers, Bi-modals and Imagers in areas of the course where their preferred cognitive style matched the presentation style (supported areas) and where their preferred cognitive style did not match the presentation style (non-supported areas).

Table 5.3

Scores obtained in supported¹ and non-supported sections of the course for Verbalisers, Bi-modals and Imagers (standard deviations are shown in brackets)

Group	N	Mean VI score	Mean Supported	Mean Non supported
All participants	51	1.28	64.7(17.6)	62.0 (15.7)
Verbaliser	17	0.87	66.3 (15.6)	61.3 (12.6)
Bi-modal	17	1.27	62.9 (17.9)	65.2 (17.9)
Imager	17	1.60	64.6 (17.6)	61.0 (16.7)

¹ Bi-modals were classified as either Verbalisers or Imagers depending on their score along the VI dimension, for the purposes of determining their supported and non-supported cognitive style.

Table 5.4 presents average time spent per screen in different sections of the course by Verbalisers, Bi-modals and Imagers. The average evaluation score for each group is also presented.

<u>Table 5.4</u>					
<u>Time spent in different sections of the course and evaluation score by Verbalisers, Bi-modals and Imagers (standard deviations are shown in brackets)</u>					
Group	N	Time spent in verbal sections average Sec/screen	Time spent in image sections average Sec/screen	Time spent in selected section average Sec/screen	Average Evaluation score %
Verbaliser	17	42.4 (17.2)	31.5 (11.2)	31.7 (8.8)	69.8
Bi-modal	17	29.4 (10.5)	22.2 (3.1)	27.5 (11.2)	74.7
Imager	17	21.2 (7.9)	18.6 (8.2)	23.5 (6.7)	76.9

It can be seen from table 5.4 that Verbalisers always spend longest in all sections of the course. The difference in time spent per screen however, was greatest for Verbalisers on preferred verbal sections of the course.

The percentage of Verbalisers, Bi-modals and Imagers, that selected text and image-based presentations in the final choice section of the course is shown in Table 5.5 below.

Table 5.5

The percentage of Verbalisers, Bi-modals and Imagers selecting text and image-based presentations in the chosen section of the course

Group	Percentage selected Visual presentation	Percentage selected Verbal presentation
Verbaliser	35%(6)	65%(11)
Bi-modal	53% (9)	47% (8)
Imager	76%(13)	24%(4)

5.3.1 Tests of significance

The next section presents tests of significance on the differences between group means in the data from table 5.3 (scores in supported and non-supported areas of the course) The results from a repeated measures Analysis of Variance (ANOVA) are presented and discussed. Non-parametric tests of significance were used on data from table 5.4 (evaluation and time spent in different sections of the course). as these were not at an appropriate form for the use of a parametric test. A Chi square test was performed on data from table 5.5 to test the significance of any differences in choice of presentation mode in the final section of the course.

5.3.1.1 Test of Assumptions

The ANOVA used in the data analysis assumes that the observed covariance matrices of the dependent variables are equal across groups. Box's Test of Equality of Covariance Matrices was employed to test the null hypothesis that they were equal. The observed value of $p > 0.05$ (0.46) allowed the null hypothesis to be accepted.

Mauchly's test was employed to test the sphericity of the data within groups which is also an assumption for the appropriate use of an ANOVA. The observed value of $p > 0.05$ (1.0) allowed the null hypothesis to be accepted and sphericity of data to be assumed.

5.3.1.2 Analysis of Variance

Table 5.6 below displays within subject effects of an ANOVA performed on scores obtained by participants in supported and non-supported sections of the course (table 5.3). The value of $p = 0.067$ for the within subject effects indicates differences between scores in supported and non-supported areas of the course are not significant. The value of $p = 0.067$, although greater than 0.05, is approaching significance. Inspection of table 5.6 however indicates that there is a significant interaction between Test scores and Group ($p = 0.025$), indicating that group composition may be influencing the dependent variable (test scores). This may explain why only a marginally significant effect was observed in the study.

<u>Table 5.6</u>					
<u>Tests of Within Subject Effects</u>					
<u>Results of repeated measures ANOVA performed on scores obtained</u>					
<u>by Verbalisers, Bi-modals and Imagers</u>					
<u>Source</u>	Type III Sum of Squares	df	Mean Square	F	Sig.
Test Scores	112.245	1	112.245	3.514	0.067
Test Scores x GROUP	255.152	2	2.613	3.994	0.025
Error (Test Scores)	1533.353	48			

Table 5.7 presents between subject effects of an ANOVA performed on scores obtained by participants in supported and non-supported sections of the course (table 5.3).

The value of $p = 0.973$ from the ANOVA for the Group variable indicates that there were no significant differences between the performance of Verbalisers, Bi-modals and Imagers on the course as a whole.

Table 5.7

Tests of Between Subject Effects
Results of repeated measures ANOVA performed on scores obtained
by Verbalisers, Bi-modals and Imagers

<u>Source</u>	Type III Sum of Squares	Df	Mean Square	F	Sig.
Intercept	205835.29	1	205835.29	761.4	0.000
GROUP	14.875	2	7.438	0.028	0.973
Error	1533.353	48			

5.3.1.3 Non-parametric tests

In this section, the use of two non-parametric tests, the Wilcoxon Signed Ranks test and the Kruskal-Wallis test, to analyse non-interval level data obtained in the study is described.

The non-parametric test, the Kruskal-Wallis test was performed on the user evaluation data for Verbalisers, Bi-modals and Imagers groups from table 5.4. The results of this analysis are shown in table 5.8 below.

<u>Table 5.8</u>		
<u>Kruskall-Wallace analysis of user evaluation data for Verbalisers, Bi-modals and Imagers groups</u>		
	N	Mean Rank
Verbalisers	17	20.82
Bi-modals	17	28.41
Imagers	17	28.76
Total	51	
Chi square		3.143
df		2
Sig.		0.208

No significant differences were found at the 0.05 level, which suggests that there was no difference in user satisfaction between Verbalisers, Bi-modals and Imagers.

A Chi Square test was performed on data from table 5.5, the number of Verbalisers, Bi-modals and Imagers selecting text and image-based presentations in the chosen section of the course.

The value of Chi square (6.29, 5 df) obtained in the test was not significant at the $p < 0.05$ level ($p = 0.278$). This means that any differences in the choice of presentation selected by Verbalisers, Bi-modals and Imagers could be ascribed to chance alone. It is suggested that the effect of Bi-modals in this test however,

was to reduce the value of the chi-squared statistic, since Bi-modals might be expected to show an equal probability of selecting either a verbal or visual presentation.

5.3.1.4 The effect of Bi-modal learners

The differences in the mean scores for supported and non-supported areas ($p=0.067$) approached significance, and there was a significant interaction between the Test Scores and Group variable ($p=0.025$). The effects of Bi-modal participants, i.e. those with both Verbaliser and Imager attributes, have been reported as complicating the investigation of the influence of cognitive style on learning. These participants would be likely to reduce the effect of any differences present in participants at the extremes of the VI dimension.

Kwok and Jones' solution to this problem was to eliminate Bi-modal learners from their investigation (Kwok and Jones 1995). Their study of navigational behaviour in followers of a multimedia course initially found no differences between serialist and holist participants. Only when they excluded versatile learners (those scoring in the middle of the serialist – holist range), from their study, were significant differences found.

In a similar way, Bi-modal learners are likely to be able to benefit from either verbal or visual modes of presentation, leading to better performance in supported and non-supported areas of the application. This may have had the effect of reducing the significance of the average differences in performance of all groups in the study as a whole, in supported and non-supported areas of the application. It was considered necessary, following the recommendation of Kwok and Jones (1995), to consider specifically the effect of Bi-modal learners. Therefore, the results of a test of differences between learners at the extremes of the VI dimension, obtained by excluding Bi-modal learners from the study, are displayed in table 5.9 below.

Table 5.9

<u>Tests of Within Subject Effects</u>					
<u>Results of repeated measures ANOVA performed on scores obtained</u>					
<u>By Verbalisers and Imagars when Bi-modals are excluded</u>					
<u>Source</u>	Type III Sum of Squares	df	Mean Square	F	Sig.
Test Scores	313.471	1	313.471	9.365	0.004
Test Scores x GROUP	9.191	1	9.191	0.275	0.604
Error (Test Scores)	1071.088	32			

The results of this analysis show that when Bi-modal participants are excluded from the study, there is a significant difference between performance in supported and non-supported areas of the course. The interaction Test Scores x GROUP is no longer significant. This suggests that it was the interaction between Bi-modal group and the Test Scores that reduced the significance obtained when they were included. No significant difference between subject effect was measured ($p=0.856$).

This result suggests that learners at the extremes of the VI dimension will benefit from learning materials that take into account preferred cognitive style. Bi-modals are likely to benefit from both verbal and image support being available.

5.4 Discussion

In this experiment, performance on a multimedia course configured for different cognitive styles was investigated. When Bi-modal learners were included in the analysis of the data obtained in the investigation, there was no significant difference in performance between participants in areas of the course where their preferred learning style, as measured by Riding's CSA test was supported and areas where it was not. Bi-modal learners are described by Riding (1991a) as learners that exhibit characteristics of Verbaliser and Imager cognitive style. These learners performed equally well in text-based and image-based sections of the course, leading to a reduction of the difference measured between performance in supported and non-supported sections of the course for learners. This produced a non-significant result ($P > 0.05$). When Bi-modal learners were excluded from the study, a significant difference between performance in supported and non-supported sections of the course was found ($p < 0.05$).

The failure to detect any difference between user satisfaction with the application between Verbalisers and Imagers could be because evaluation was carried out at the end of the experiment. Participants had experience of similar amounts of exposure to supported and non-supported sections of the application, there was little difference in their appreciation of the application as a whole.

There was no difference between time spent in supported and non-supported areas of the application by groups with different cognitive styles. The reason might be due to the interaction between differences in motivation and skill in supported and non-supported sections of the course. All groups spent less time in the image section of the course than in verbal sections, (table 5.4). It is suggested that Imagers were able to obtain information more effectively than Verbalisers who were less motivated and therefore spent less time there. Verbalisers spent more time in the verbal sections because the serial nature of text meant that it took longer to obtain information from it than does from an

image. It is possible that Imagers lacked motivation, skimmed text more and finished sooner. Stoney and Wild (1998) have investigated the influence of motivation on performance, suggesting that motivation is an important factor likely to influence performance on courses.

5.4.1 Implications for the individual configuration of learning materials

Paterson and Rosebottom (1995) consider individual user characteristics to be essential in the design of multimedia applications for learning. Learning style and strategy are important in this process according to them. This suggestion is supported by the results of this investigation, where learners at the extremes of the VI dimension were shown to benefit from the configuration of presentation to suit their preferred cognitive style.

Pillay et al (1998) have suggested that learning materials can be designed to accommodate preferred cognitive styles, based on an investigation of cognitive style and performance. Although they failed to find significant differences in the performance of learners with materials matched and mismatched to their cognitive style, they conclude that subject content may have an affinity for certain cognitive styles. They further conclude that the design of CBI materials can benefit greatly by considering the needs for personal learning styles. Liu and Reed (1994) also suggest that there is a great potential for using hypermedia to support individual learning style.

In the previous chapter, an investigation into language level and the configuration of multimedia learning materials was performed. It was found, that learners with poorer language skills performed better when language support was provided. The provision of this support did not benefit learners who had good language skills. In this study, it was shown that learners at the extremes of Riding's VI dimension performed better in supported areas of the course than they did in