The guiding process in discovery hypertext learning environments for the Internet

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The Guiding Process in Discovery Hypertext Learning Environments for the Internet

by

Kingsley King Wai Pang

Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy at Loughborough University

19th October, 1998

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This thesis is dedicated to my parents
Man Kuen and Yu Kuen Pang
Abstract

Hypertext is the dominant method to navigate the Internet, providing user freedom and control over navigational behaviour. There has been an increase in converting existing educational material into Internet web pages but weaknesses have been identified in current WWW learning systems. There is a lack of conceptual support for learning from hypertext, navigational disorientation and cognitive overload. This implies the need for an established pedagogical approach to developing the web as a teaching and learning medium.

Guided Discovery Learning is proposed as an educational pedagogy suitable for supporting WWW learning. The hypothesis is that a guided discovery environment will produce greater gains in learning and satisfaction, than a non-adaptive hypertext environment. A second hypothesis is that combining concept maps with this specific educational paradigm will provide cognitive support. The third hypothesis is that student learning styles will not influence learning outcome or user satisfaction. Thus, providing evidence that the guided discovery learning paradigm can be used for many types of learning styles.

This was investigated by the building of a guided discovery system and a framework devised for assessing teaching styles. The system provided varying discovery steps, guided advice, individualistic system instruction and navigational control. An 84 subject experiment compared a Guided discovery condition, a Map-only condition and an Unguided condition. Subjects were subdivided according to learning styles, with measures for learning outcome and user satisfaction. The results indicate that providing guidance will result in a significant increase in level of learning. Guided discovery condition subjects, regardless of learning styles, experienced levels of satisfaction comparable to those in the other conditions. The concept mapping tool did not appear to affect learning outcome or user satisfaction.

The conclusion was that using a particular approach to guidance would result in a more supportive environment for learning. This research contributes to the need for a better understanding of the pedagogic design that should be incorporated into WWW learning environments, with a recommendation for a guided discovery approach to alleviate major hypertext and WWW issues for distance learning.
Acknowledgements

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To my funding body, the EPSRC.

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To Suski, to Paul Pantry from the Distance learning Group, Tony Clarke in the Department of Computer Studies for their advice on Electronic Logic.

To my friends near and far. A special mention must go to Parminder, Lloyd, Paul, Geurng and all those who have supported and had faith in me.

To my sister, her husband and my brother for keeping me smiling.

This is dedicated to my father and mother who have always been there.
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Chapter One

Introduction

1.1 Introduction to the Thesis

This research centres on learning using the guided discovery educational paradigm to construct a hypertext-based environment on the Internet. The aim is to provide a single user system to teach over the World-Wide Web (WWW). The subject domain selected was electronic logic, although the results are applicable to other subject areas.

The specific research educational pedagogy examined is Guided Discovery Learning for future tutoring and learning environments which use the Internet to deliver teaching material. Weaknesses have been identified in current systems that purport to provide distance learning. These are:

- A lack of support for cognitive engagement with the material.
- Disorientation when navigating across the knowledge domain.
- Lack of individualisation of the material and in system support.
- An absence of a clear overt, pedagogical approach to the design of WWW learning environment.

The aim is to provide individualistic support that is adaptive to the learner’s current state of knowledge. It is suggested that using the Internet for learning purposes is viably different from other uses of this medium. The efficacy of hypertext web pages to promote learning have yet to be proven. Educational environments that are reactive to individual user needs remain largely unexplored in the context of research on the
Internet and Education. The difficulty is in producing a system that will be able to adapt sufficiently to providing guidance and effective learning from a distance.

The need is for a system that will permit learner-led exploration but utilising a knowledge base to control the discovery process. It is proposed that there is a requirement for:

- A system using a tutoring module to carry out decreasing intervention.
- Need for control of both the navigation of the information space and sequencing of the material.
- Formulation of discovery steps composed of structured questions.

Related to this are issues of:

- Hypertext and implications for learning.
- Using the WWW as more than just a medium for material delivery.
- Implementing guided discovery principles in a computerised environment.

The guiding process is the ability to direct the learner, during the exploratory process, when using a hypertext environment on the Internet. The underlying premise is that there needs to be a combination of other components into the learning environment in order to provide different types of overt and covert guidance.

1.2 Hypertext

This thesis examines several areas of hypertext, from general problems such as disorientation and navigation, to specific problems encountered when using hypertext for learning. It will be shown that there is a requirement for guidance in hypertext when it is placed on the Internet.

In this research, hypertext is seen as non-sequential text with non-animated pictures. The linking between the nodes defines the characteristic of hypertext; being both non-linear and non-hierarchical (Angelides and Tong, 1995). Browsing in a non-
hierarchical manner is characteristic of a hypertext environment, with the learner traversing through a network of interconnected nodes.

There are clearly discernible differences between the computer technology used in the past and the emerging web technology. Navigating the Internet is primarily through the selection of hypertext links in the web page. The main attraction of hypertext is that it supports non-sequential educational approaches by encouraging free-association, which is seen as characteristic of human thought. The learners can choose their own direction through the information, exploring what is relevant. This emerging technology is predicted to create a change in long established methods of teaching (Benyon, Stone and Woodroffe, 1997; Debreceny, Ellis and Chua, 1995).

But the problem of increased flexibility of access is an increased cognitive load on the user, resulting in the disorientation problem. The cognitive demands of making decisions about navigation, while trying to integrate the contents, can be cognitively demanding with users experiencing difficulty deciding what to read next.

Research into exploratory systems allow a certain degree of tutorial and learner-led control, but the degree to which this should take place remains contentious. Hypertext in contrast to traditional behavioural Computer Assisted Instruction (CAI) and model-driven Intelligent Tutoring Systems (ITSs) supports the shift towards exploratory learning. When applied to a learning context, the strength of hypertext is that it allows the possibility of freedom and guidance in the educational process.

In terms of the use of hypertext, this thesis examines how to alleviate the navigation and disorientation problem but only as part of a wider approach for making hypertext beneficial for learning. Navigation and disorientation contribute to part of the symptoms of an instructionally ineffective learning environment. In this respect, investigating this issue will help to determine principles for encouraging structured learning whilst maintaining the freedom to explore in a hypertext environment, something which at first may appear to be a paradox for the exploratory behaviour that hypertext encourages.
The literature suggests that there is no instructional design theory which can provide conclusive evidence of the best way to design hypertext systems for learning which would best promote learning in a World-Wide Web (WWW) environment. There is a marked paucity of overt pedagogical strategies in the design of many of these systems. This is the main postulate of this thesis, to explore beneficial ways that guidance techniques can be built into the system where unstructured, non-adaptive hypertext is not sufficient in supporting learning.

1.3 World-Wide Web

The Internet can be viewed as a 'network of networks'. The World-Wide Web (WWW) is a means of navigating through the Internet, providing a visual display of the data in the form of hypertext documents (Berners-Lee et al., 1994). The ease of use and world-wide access on multiple platforms is why the WWW is so successful. This is also the reason why the WWW provides so much appeal to educators who want to provide distance learning, due to the ability to easily select web pages.

The literature has proven that the WWW (referred to as the 'web') offers unexplored potential for distance learning and modes of alternate delivery of educational material. Questions could centre on the use the web for learning. It can act beyond being just another delivery system and instead create applications which can provide education in a radically new way that other previous technologies had not (Eklund, 1995). The move is towards the 'virtual university' which may only exist online and will play an increasingly major part in higher education (Mumford, 1995).

One of the main paradigms of using World-Wide Web (WWW) is that of browsing. Documents are linked together in hypertext links. Clicking on a link signals the browser to fetch the other document from wherever it is stored. The main strength of hypertext is to browse the material and it remains a distinguishing characteristic of web pages with users 'surfing' the Internet. Navigation and disorientation issues remain at the forefront of research into hypertext systems that use the Internet to carry out learning. The assumptions built into web pages, that have been derived from
hypertext, can be criticised for suffering from the same lack of established data about the effectiveness for promoting learning.

Therefore it will be shown in this thesis that a guidance aspect needs to be embedded into the web pages, to provide for sufficient cognitive support for promoting meaningful learning. Structure alone cannot provide the support that the learner needs, therefore tutoring material placed on the Internet should be interactive and contain a instructional element. The recommendation in this thesis is that the instructional element should be a guided discovery approach, which will provide the structure in the hypertext which is needed. The integration of cognitive tools and the incorporation of Intelligent Tutoring System (ITS) functionality will offer some support.

1.4 Project Achievement

The aim of this project is to determine how specific guidance in a discovery hypertext learning environment for the WWW would affect learning outcome and user satisfaction. Allowing the learner complete freedom over the navigational process has been regarded as the main educationally attractive strength of hypertext (Allinson and Hammond, 1990; Markle, 1992; Landow, 1990). However it has been identified that the ‘lost in hyperspace’ problem and cognitive overload is detrimental to learning (Conklin, 1987). Furthermore hypertext does not provide enough cognitive support in the learning process itself. There is a lack of research establishing the efficacy of learning from hypertext and a lack of clear guidelines for building systems which have a clear pedagogical approach to learning. It is this lack of an overt educational approach that has been cited as a major weakness of distance learning systems on the Internet. The main emphasis of this project is to establish a framework for analysing how a guided discovery style of teaching can take place, to implement this style and to assess the contribution of this to the current body of knowledge on the WWW and learning.

The addition of a concept map tool was included in some of the experimental conditions to determine if this would re-enforce learning, especially with the guided
Several versions of a hypertext discovery system were constructed consisting of: a guided discovery learning condition, a ‘concept map only’ condition and an unguided, conventional hypertext condition. A measurement was made of learning outcome, user satisfaction, and whether it was inter-related to learning style, presence of guidance and access to a concept map.

An investigation of learning styles was undertaken to determine what effect guided discovery would have. The assumption is that there are activities congruent with specific learning styles (Honey and Mumford, 1992, Davis, 1993). If the educator is able to determine the individuals’ learning style then activities can be created which may meet these needs, or the learner can select tasks which suit this particular style of learning.

The results gathered from this research suggest the conclusions that: (1) providing guidance can lead to significantly greater gains in learning outcome, (2) the learning environment should be able to provide individualistic instruction and (3) regardless of different learning styles the subjects will achieve increased understanding of the domain knowledge. Because guidance assumes shifting navigational control to the system, it could be predicted that the student would feel constrained by the lack of control. This was not found to be the case as those in the guided discovery condition were comfortable with this. The amount of guidance given by the system did not create the perception of being restricted in the navigational process (as ascertained by the answers given in the user satisfaction questionnaire and the semi-structured interview). It is put forward in this project that guidance should take place in a particular form and at specific points in the discovery sequence.

The main achievement of this project is to raise the importance of using a structured, educationally reasoned approach to the design of Internet systems for learning. There have been too many assumptions about learning built into current systems without a defined approach to design or subsequent rigorous scientific analysis. A model of guided discovery has been put forward that can be used to incorporate hypertext, WWW and distance learning issues. The methodology for implementing guidance constructs has been proven to be beneficial for future hypertext environments.
1.5 Structure of the Project

The overall structure of the project follows several strands. The thesis begins initially with an outline of Computer-Aided Instruction (CAI) as a method for supporting learning, followed by an examination of educational hypertext; and the use of guided discovery as the educational paradigm for structuring hypertext both at the node level and at the hypertext network level.

Chapter two charts the shift in educational paradigms in the design and construction of computer-assisted instruction. The different educational approaches make assumptions about the learner and the support needed for the learning process. The aim is to place the guided discovery approach within the context of these competing educational pedagogies and CAI systems.

Chapter three will examine specific research issues related to discovery learning. A definition of discovery learning will be given and systems purporting to use this will be discussed. The merits and demerits of this approach will be used to argue for a guided discovery learning approach derived from discovery learning.

Chapter four will examine guided discovery as a teaching style. Teaching style is seen as composed of many pre-specified steps to promote learning. An examination of guided discovery in the context of a human teacher-student model derives principles that can be applied to a 'system-student' guided discovery interaction process. A framework is put forward for the guided discovery approach used later in this project.

Chapter five examines the research issues specific to using hypertext as a tool for learning. The primary problems for educational hypertext are navigation and disorientation. In addition there remains insufficient evidence for establishing the efficacy of hypertext for learning. The WWW is basically a hypertext environment, hence some of the difficulties in using hypertext for learning are echoed in WWW and learning, as the underlying nature of the navigation is tangibly similar.
Chapter six moves the discussion onto general research issues for the WWW and distance learning. The growth and ease of use of the Internet have led to increases in the use of this medium for learning and examples are given of different methods on the WWW.

Chapter seven continues the discussion from chapter six, drawing together some of the strands from hypertext and WWW research. Specifically in examining the issues related to using the web pages for educational purposes. For example learner control, instructional design and semantic memory models related to learning.

Chapter eight links the framework put forward in chapter four into an architecture for a guided discovery approach for the WWW and learning. The construction of all the components of the system will be explained such as interface design, online testing and hardware/software decisions. An extension of the framework is given to strengthen the guidance aspect of guided discovery learning.

Chapter nine describes the evaluation strategy for determining what is measured and how it is measured. Because the research area is learning there needs to be a measure of specific effects on using the different systems. The first is a measure of learning outcome (exam score), the second is a measure of user satisfaction (both in terms of a questionnaire and as an interview).

Chapter ten provides a statistical analysis of the results found from the experiment, learning outcome, user satisfaction, with summaries from the user's navigation history files and interview responses.

Chapter eleven posits the result analysis in relation to past research findings. A discussion will centre on evaluating the research hypothesis put forward, and explanations will be given of the results.

Chapter twelve provides a discussion of future work to determine ways the guided discovery approach can be extended and applied. Conclusions are drawn from the statistical results to determine the value of using the guided discovery paradigm for WWW hypertext environments.
Chapter Two

Educational Pedagogy and CAI

2.1 Introduction

There are many terms for the use of computers to promote learning. The term Computer-Assisted Instruction (CAI) will be used to describe other keywords that have been used in this area such as Computer-Based Learning (CBL), Computer-Aided Learning (CAL), Computer-Mediated Instruction (CMI) and other similar terms used to describe the use of a computer to support the learning process.

The purpose of this chapter is to outline changes in CAI. This is not carried out in a chronological order but by educational paradigms. The chapter will be used to illustrate some of the research carried out in this project in relation to past CAI research. It will isolate characteristics of different approaches to teaching and draw together findings that have influenced the design of the guided discovery system used in this project.

This section will discuss a move from objectivist behavioural models to a shift towards constructivistic models of learning (Wiles and Wright, 1997; Mayes, 1993). The difference in these approaches is that behavioural-type models (characteristic of early applications of computers for learning) examine observable student behaviour. The emphasis is on the actions of the learner in relation to specific tasks set by the computer, examining factors such as the provision of certain reinforcers to obtain specific types of actions. This is in marked contrast to cognitive learning theories which look at less observable changes in the behaviour of learners. But more specifically at concept formation and overcoming misconceptions in educational
scenarios such as: problem-solving, promoting of metacognitive skills and mental models that the learner has of the system and the domain. These two approaches are representative of a change in the educational paradigms used in CAI. The research in this thesis also reflects this shift; supporting a move towards an educational approach for cognitively supporting the mental operations of the learner during the learning process. The paradigmatic shift from behaviourist learning is discussed with illustrations of systems that exemplify these shifts.

The educational psychology which structures the characteristics of the guided discovery paradigm will be discussed in chapter 4, as these reflect the psychological theories used in the research in this thesis. This chapter is structured to chart the growth of these competing paradigms, looking initially at linear programs and moving onto hypertext as a cognitive tool for promoting learning.

The last part of this chapter will examine the place of hypertext and guided discovery learning in the context of other systems according to certain criteria. The features that distinguish the system in this experiment from other systems, will in turn affect what evaluation strategies are used to determine which learning outcomes are measured and how the hypothesis will be investigated. The aim is to place the research in this thesis in terms of other systems that use alternative educational pedagogical approaches.

2.2 Approaches to Teaching Using CAI

The first types of CAI were referred to as 'traditional programmed instruction' (Romiszowski, 1992). A teaching programme can be regarded as a course prepared by the teacher or tutor before the learner is allowed to use the material. It is generally presented to the student one stage at a time, with each stage requiring the user to provide a measurable response. This may be the answering of a question, taking a decision or solving a problem set by the system. The student's response serves two main purposes. Firstly to show that they are actively engaged in the learning process and secondly to measure how far they have progressed in this process. This can be
used by the student to assess self-progression or by the course/system designer to make any changes to overcome any weaknesses in the teaching process.

In terms of responses, the system must be able to garner responses which the learner should be able to use, to gauge how well the learning is progressing in relation to a expert model and for the system designer to identify any changes in the structuring of the material that is required. In early CAI this was carried out in two ways, either as linear programs or as branching programs.

2.2.1 Linear Programs

The educational theory is based on an acquirement of skills. This skills model of learning is derived from Skinnerian psychology (Skinner, 1968) and progressive reinforcement for particular types of respondent behaviour. The method of operant conditioning, initially from research on animals, focused on rewarding the subject if the desired response was obtained. The presentation of this stimulus was based on arranging reinforcement at particular stages of the learning. This is mirrored in the operation of linear programs, in rewarding correct responses at every stage of the learners' responses. Because the desired behaviour is complex, teaching proceeds by reinforcing approximations to the desired behaviour.

In terms of the sequence of instruction and interaction, the student may be presented with the correct response immediately after user input. It is quite likely that the response given by the user is obviously correct and the learner is allowed to proceed to the next frame (or stage). If there is a discrepancy the learner must re-read the frame before proceeding further in the material. Eventually the learner will be allowed to proceed to the next frame in the sequence, following a linear sequence of frames. It is the task of the courseware designer not to provide a linear sequence that increments at a greater pace than the learner can cope with. Otherwise the learner will provide a response without knowing why it is wrong.

The learner cannot see why the response is wrong and the system is usually unable to provide enough support to overcome this 'gap' in knowledge. If a sequence is too difficult for the learner to follow, the courseware designer will modify the sequence.
by adding extra practice material, re-wording and more prompts. The result is a
typical linear program composed of a large number of relatively small frames, studied
in sequence by all students regardless of their previous knowledge. In terms of
learning outcomes, these types of programs are used for acquiring repetitive,
procedural tasks (Hannafin and Peck, 1988).

2.2.2 Branching Programs

The suggestion that the student learns by being ‘told’ is as prevalent in branching
programs as it is for linear programs. The aim is to provide a greater degree of
individualisation, through the analysis of the learner’s response and providing
feedback more appropriate to certain misconceptions that a particular student may
have. This also allows a greater degree of learner control.

The student is presented with several alternatives. The student may make a response
and then compare it with the selection. If the response is correct then new material
will be displayed. If the learners’ response is incorrect, then the learner is branched to
a remedial frame or sequence of frames. Pattern-matching techniques allow answers
to be partially acceptable rather than being totally correct as in the previously
discussed linear programs. Instead those who answer wrongly will work through
extra material before being allowed to re-join the main stream of the material. The
task of the courseware designer is to predict a set of possible responses and to provide
material to overcome these predicted responses. This is difficult to do; to be able to
foretell problems that the learner will experience when using the system requires
considerable insight.

There has been a tendency for a mixture of linear and branching sequences in the
same program, but the suitability of this is dependent on the subject domain. Few of
these characteristics of ‘traditional’ programmed instructions have remained, with the
criticism that some of these features that are claimed to support learning are invalid.

Leith (1969) has evaluated these characteristics and provides a critical summary of
such systems. They have been criticised for leading to: (1) boredom due to too-small
steps in the learning material, (2) no real detection of errors during the actual learning
process rather than afterwards during post-testing, (3) they proceed a lot slower than they are capable of (4) insufficient individualisation of system responses, (5) identical sequencing regardless of the user’s previous knowledge, and (6) inadequate feedback.

Carbonell (1970) sees the learning experience as being too similar to reading from a textbook in a linear fashion. Both types of branching concentrate on systematic presentation rather than allowing the learner greater interactivity and control in the learning process, thereby treating learning as the acquisition of a particular skill rather than the quality and depth of what is learnt. This is similar to paper-based programmed instruction, except that a computer is used to present the material. Therefore the computer is treated more as a presentation device concerned with sequencing material rather than as a system for active, individualised tutoring.

2.2.3 Drill and practice

Drill and practice designs provide practice for defined skills in the form of immediate feedback to the student for each response given. There is also usually some form of correction or remediation for responses which are incorrect. It is not typically the function of ‘drills’ to teach new concepts, skills or information. Generally, drill-and-practice designs are used to reinforce skills taught elsewhere. At the heart of drill-and-practice activities is repetition combined with a limited feedback system (Ferguson, 1992).

Drill-and-practice has been criticised as being a ‘lesser form’ of CAI. Even though drill-and-practice is not very spectacular, it is one of the main uses of CAI for learning routine and repetitive tasks (Romiszowski, 1986). There are a variety of drill-and-practice formats. Many are disguised as games (e.g. word association games). Others are simulations, such as programs to train and drill typing skills.

Some drill-and-practice programs have been classified as ‘generative systems’ (O’Shea and Self, 1984). Such systems have the ability to generate and solve problems meaningfully. The intention was to do away with all the pre-stored teaching material, problems, solutions and associated diagnostics and generate them. Uhr (1969) implemented a series of systems which were tailor-made to a student’s

The principal advantage of CAI drills is their ability to provide an intensive and controlled opportunity for students to refine their skills. They provide an unlimited source of teaching material; providing as many problems as the student need to achieve some level of competence. Drills can also be designed to detect error patterns and to adapt the level of difficulty of problems to the students. Some form of drill-and-practice is necessary in order to develop basic skills or to reinforce essential knowledge.

A major shortcoming of drill-and-practice systems is the restriction to well structured domains, such as mathematics. Very few subjects are sufficiently well structured that they can be cast into the generative mould. Another common criticism is that such systems often appear more like flash cards or tests, than instruction. These programs do not possess any real knowledge of the domain and therefore cannot teach the student how to solve the problems. The gap between the student's cognitive processes and the internal workings of the programs is too wide (Sokolnicki, 1991).

The most important issue in considering the assets and limitations of CAI drills is their 'potential versus their status' (Romiszowski, 1992). Some systems are poorly conceived and thus limited in their effectiveness. Whilst systems based on inadequate design methods should be rejected, some researchers stress that:

'we cannot reject the value and potential of intelligently designed CAI drills ' (Hannafin and Peck, 1988).

Therefore drill and practice will continue to be one of the main uses of CAI whenever there is a requirement to learn routine and repetitive tasks.
2.3 Simulations

CAI simulations approximate, replicate, or emulate the features of some task, setting, or context. Simulations are used when the costs of alternative teaching systems are prohibitively high, and when there is a need to study the concepts of interest in real time, in a controlled, relatively risk-free environment (Alessi and Trollip, 1985).

A simulation is a dynamic model that approximates some aspect of the real world. Generally these models are of processes or systems. The student takes an active role in the environment. This can be hypothesis-driven, with the user testing a hypothesis by manipulating variables in the environment and examining the outcome.

Computer simulations present a particularly complex form of CAI. Possible advantages are that they may reduce costs, time and danger, highlight what is important educationally, and enable otherwise impractical investigation to be carried out (Self, 1985). Interactive graphical simulations can be presented in powerful environments that allow learners to practice carrying out tasks and to see the results of their actions. When presented in association with instructional functions that respond to individual learner needs, simulations can support training costs far below those incurred in operating the real system, while providing consistent instruction.

Their limitations are related to their design and implementation. Simulations can pose a significant planning challenge for lesson designers and can be complicated to program. Another problem is that simulations are simplifications. They are idealisations intended to emphasise what is essential to understanding a particular aspect of the system being simulated.

In the mid-1980’s simulations were considered the most used mode of CAI (Romiszowski, 1992). Ellington et al., (1981) provides a review of simulations ranging from physics to economic principles, highlighting their application in many domains. Two typical examples are given below.
SOPHIE is an intelligent simulation training system that produces simulation-based inferences during interactive training (Brown, Burton, & Bell, 1975; Brown & Burton, 1975). SOPHIE generates textual responses to student queries and answers. Students inquire about indications and test results by typing, as it is not a graphical system. In SOPHIE-III (Brown, Burton, & deKleer, 1982), the reactive style of earlier versions of SOPHIE is supplemented with a pedagogically active component that estimates and responds to student needs.

Steamer (Hollan, Hutchin & Weitzman, 1984) provided a simulation of a steam propulsion system and provides a good example of a typical simulation environment. With a comprehensive graphical interface, it was used as an experimental tool to investigate mental models, graphical interfaces to interactive inspectable simulations, conceptual fidelity and implementation philosophy; using finding from AI programming environments for the design and implementation of computer-based instructional systems. Most of the genuine AI aspects of Steamer are derived from the knowledge representation function. Steamer is able to provide various perspectives of the plant derived from models used by human experts for example; and the system would continuously maintain a flexible model of the state of the simulation and the student. Simulations are discussed further in chapter 3 as they were one of the first CAI to use discovery learning techniques for teaching.

2.4 Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) provide individualised system-driven tuition. These systems control the learning situation and adapt their content and style of tuition by modelling the student’s conception of the subject. These mark a shift towards the cognitive aspect of learning.

The ability of the ITS to model the student’s knowledge is dependant on its ability to model the subject domain knowledge to a high level of fidelity. An ability to compare the two models enables individualised tuition. Unfortunately, these requirements lead
to highly domain-dependant representational schemes. The pedagogic abilities are, therefore, non-transferable across subject domains.

For a tutoring system to be regarded as intelligent, it needs to fulfil three criteria (Angelides and Tong, 1995). Firstly the system should know the subject matter in-depth enough to be able to draw inferences or solve problems concerning the domain. Secondly it must be able to deduce a learner’s approximation of the domain knowledge. Thirdly the system should have tutorial strategies that reduce the difference between the expert and the student performance. These are the three components that make up an ITS: (1) the expert module or domain expert, (2) the student model, and (3) tutoring module. The interface module mediates the interaction between the ITS and the student. These are discussed as separate sections and are included because they are used in the design of the guidance component in the guided discovery condition.

However not all conversational, in-depth dialogue, ITS methodologies are based on the concept of the computer learning about the learner and thus improving and further individualising the instructional strategy being used. It is possible to build some very complex interactive dialogues purely on the basis of deep questioning techniques and multi-faceted analyses of the responses given by the student.

A drawback with a requirement for a fine grain representation of knowledge is the unacceptably long development time often involved (Angelides and Tong, 1995). Domain independent systems are now being developed to provide re-use rather than continually starting development from scratch. This development is achieved by separating domain-dependant information from the pedagogical knowledge (Vassileva, 1990) and enables aspects of a systems knowledge to be re-used in other domains. The pedagogic philosophy of system-controlled learning, whereby the student is treated as a “dumb patient” (Megarry, 1988) has also been questioned.

One of the most significant outcomes from ITS research was the agreement of a common architecture for an ITS (Barr and Feigenbaum, 1982). The structure of an ITS is composed of three modules (expert module, student module and tutoring module), reflecting the ‘what, whom and how’ paradigm for tutoring, plus an
interface for student/system communication (Polson and Richardson, 1988; Wenger 1987; Mandl and Lesgold, 1988).

2.4.1 The Expert Module

The expert knowledge module is also known as the domain expert, and consists of domain knowledge for instruction. It provides the domain intelligence (Anderson, 1988) and serves as the source of knowledge to be presented to the student: including generating questions, explanations and responses; allowing a comparison between the learner and the expert in that particular subject domain. The central issue in creating an expert module is representing the knowledge.

There are different approaches to encoding knowledge into the domain model. A particular approach is a "black box" model of the domain knowledge. The black box model (Anderson, 1988) uses a criterion referenced knowledge base. The content domain is organised into an existing framework manipulated by the system. The computer can assess student performance without the need of "human intelligence". The criteria for acceptable performance are clearly identified. If the input behaviour does not meet the criteria, the computer will inform the student of the performance error and recommend possible solutions. The dialogue between the student and ITS is very simplistic, attempting to reason about the knowledge without explicitly coding it. It is more of a reactive tutor telling the learner what is right or wrong; essentially taking a surface level approach to the tutoring. The computer does not provide detailed explanation of its reasoning.

Another model is the Production System, known as a rule-based system. A production system analyses and synthesises large quantities of knowledge to solve problems. Declarative and procedural knowledge are integrated in a production system. The declarative knowledge formulates a database of facts and the procedural knowledge provides the rule base in IF-THEN or WHEN-THEN relationships.

A rule is a "chunk" of information which when matched with conditions in the environment, triggers a specific behaviour. A rule consists of a set of facts and a set of actions. All conditions on the IF side of the rule are matched to a set of facts in the
A set of behaviours are identified on the THEN side of the rule. Intelligent Tutoring Systems have expanded the application of the production system by recognising that humans have the capacity to solve problems using various reasoning methods. The Intelligent tutoring system assesses student performance to determine if the behaviour conforms to the prescribed "expert" rules. If the performance does not match the rule, the ITS assumes the role of instructor by diagnosing the student's weaknesses and prescribing appropriate remediation. The basic tenets of this rule-based system is applied to the guidance component of the guided discovery system in this project, in order to provide individualised instruction according to navigational behaviour and online test results. This can provide limited adaptivity for supporting the learning process.

Criticisms of the knowledge representation within the ITS approach continue to prevail, with it often regarded as being too shallow in the sense that it can be used to solve problems, but not to fully explain or justify the solution. There have been many methods to represent knowledge, but the criticism has been that they are of limited use in representing very specific domains. In addition, ITS designers need a deeper understanding of human cognitive processes and how they can be modelled (Anderson, 1988). Basic research is also needed into building a meta-theory of expert knowledge that shows how declarative, procedural and causal knowledge can be incorporated into an ITS (Richardson, 1988). Although it has been shown that when experts do try and formalise their knowledge for an ITS that it can help design a structural learning process with specific sub goals as learning episodes (Elliott et al, 1995; Kibby and Mayes, 1989). There are a variety of knowledge architectures and only a few have been discussed in this section, with the system used in this project being based on a production-type expert module. This is discussed in more detail in Chapter 8 about how it has been applied in the architecture of the guided discovery learning system used in this project.

2.4.2 The Student Model

An ITS diagnoses a student's current knowledge of the subject matter in order to individualise the instruction according to perceived needs. The student model refers to the dynamic representations of the emerging knowledge and skills of the student.
No intelligent instruction can take place without an understanding of the student. The student model is an explicit representation of the student's skill and should include aspects of the student's behaviour and knowledge which may offset performance and learning (Self, 1974; Self, 1988).

The input to the student model is via interaction with the system; the output is dependent on how the student model is used. Common uses for the student model may take the form of automatic advice, generating new problems and changing material to overcome misconceptions. A student model is usually composed of three types of information: the type of domain knowledge (declarative, procedural or causal), bandwidth (amount and type of student input) and differences that the learner has in terms of missing conceptions/misconceptions (e.g. an overlay model).

The student model establishes the framework for identifying the student's misconceptions and sub-optimal performance. The structure of the student model can be derived from (1) the problem-solving behaviour of the student, (2) direct questions asked of the student, (3) historical data (based on assumptions of the student's assessment of his skill level, novice to expert), and (4) the difficulty level of the content domain (Barr & Feigenbaum, 1982).

The simplest kind of student model is represented as a subset of the expert model at particular intermediate stages of the learning process. This overlay model (Goldstein, 1982) shows which pieces of knowledge are believed to have been acquired and verified by the student. A more formative student model provides explicit representations of the student's incorrect version of the target knowledge for remediation purposes. This is the 'buggy approach' (Burton, 1982).

In the 'buggy' model the ITS compares the student's actual performance to the user model to determine if the student has mastered the content domain. Advancement through the curriculum is dependent upon the system's assessment of the student's progress level. The student model contains a database of student misconceptions and missing conceptions. This database is known as the "bug library". A missing conception is an item of knowledge that the expert has but the student does not. Bugs are identified from the literature, observation of student behaviour and learning theory.

With student models there is a tacit assumption that tutoring based on fine-grained student models will be more effective than using course-grained models. Fine grain models are more powerful in that they have more detailed information about the cognitive processes of the learner. A lack of research in this area means that there are no clear-cut guidelines about when fine grain models are appropriate. Another difficulty is the "intractable problem" encountered in student modelling, that of building valid models of the students cognitive processes (Self, 1990). The student model selected for use in this experiment is discussed further in chapter 8, along with possible solutions to some of the problems and compromises of user modelling.

2.4.3 The Tutoring Module

The tutoring module is used to provide an instructional strategy to the learning process. This component contains the pedagogical approach to structure the interaction of the system and the learner (Haliff, 1988). Pedagogic activities comprise tutorial strategies to provide advice, support, explanations, administering problem-solving activities and tests to update the student model.

The tutor model may contain a spectrum of tutoring styles (Angelides and Tong, 1995) and should carry out the following: (1) it must have some control over the selection, (2) sequencing and presentation of the material, (3) be able to deal with student queries (4) and determine when the student needs help. Some are expository tutors, who primarily teach factual knowledge and inferential skills, others are procedural tutors, teaching skills to manipulate factual knowledge. The tutor model also has knowledge about how to enable learning, or provide the best conditions to promote learning to take place. The assumption that persists is that practice will lead to higher levels of skilled performance. In terms of dividing the material to be learnt, it should be divided into manageable units composed of achievable smaller instructional goals, with the material sequenced in a way that conveys structure to the learner and allows the tutor to evaluate progress.
The ITS actively processes student inputs and diagnoses the level of understanding or misunderstanding of the knowledge domain. The tutoring module exercises some control over the selection and sequencing of information by responding to student questions concerning the subject domain and in determining when the student needs help and what kind of help is needed (Halff, 1988). An effective ITS will cope with the continually varying needs of the student. ITS diagnoses the student's characteristic weaknesses and adapts the instruction accordingly. As the student's level of proficiency increases, ITSs will ideally conform to the evolving skill level of the student.

This ability to determine when and how to intervene is a primary part in structuring guided discovery learning (Mosston and Ashworth, 1990), and is related to areas such as learner control (discussed in section 5.8) and navigation issues in hypertext (discussed in section 5.6.1). The aim is to find a degree of learner-control in relation to control by the system, and the subsequent implications that this has on learning outcome. Clancey (1987) provides a review of ITSs and some of the methods used to intercede during the learning process.

Another issue that has received research in this area is the applicability of tutorial strategies to different domains. Whether a particular pedagogical approach has value in teaching in diverse educational settings rather than an experimental scenario, as is often the case with these systems. Current research in ITSs has tended to shift towards multiple tutoring strategies in ITSs (Angelides and Tong, 1995; Srisethanil and Baker, 1995), which are still at a stage of infancy. The use of guided discovery learning as a teaching strategy still remains largely neglected as an educational paradigm for the WWW (albeit less so for hypertext).

2.4.4 The User Interface

The user interface determines how the student interacts with the ITS and in turn how the student interacts with the educational domain. A well designed interface will allow the ITS to present instructions and feedback in a clear and direct way and give students a set of expressive techniques for stating problems and hypotheses to the ITS. In addition, most ITSs allow students to interact in the domain being tutored. There
are different ways in which a domain can be characterised and this is where the effectiveness of an interface for tutoring lies - in defining the way that students think about the concepts in which they are being tutored (Miller, 1988). Interfaces can allow users to become direct participants, as often found in simulation environments or allow control through an intermediary via, for example, command languages or pull-down menus.

Another area related to interface design is how to create conceptual models and how to convey this to the learner. Conceptual models are used to guide users' interactions with the system. They allow reasonable guesses about likely ways to handle novel problems, about probable reasons for errors and optimal ways to recover from errors. A desirable conceptual model of an interface should have the following characteristics: clarity, coverage and a sound level of abstraction of the system (Miller, 1988). The work on direct manipulation interfaces discusses the use of iconic design in relation to the domain of learning (Shneiderman, 1998; O'Malley, 1990).

2.4.5 Current Tutoring Strategies

Some of the tutoring strategies currently in use are Socratic diagnosis, learning through exploration, apprenticeship, successive refinement and practice.

Socratic diagnosis varies in its definition. It is based on the socratic dialogue. This is in the form of a question and answer sequence directed towards exposing the student’s misconceptions. The tutor’s role is to firstly detect the misconception and then make the learner realise that there is a flaw in their domain knowledge through a series of educational interactions. WHY (Stevens et al., 1982) uses a strategy labelled as Socratic. When the student makes a mistake at a level involving a specific concept, the tutor will switch to a sequence of questions regarding subconcepts of the erroneous concept. If the student makes an error at this level then it may be further broken down into its constituent concepts. The major difference between this strategy and true Socratic tutoring is that instead of diagnosing each of the misconceptions first, in WHY the remedial action is used as a diagnostic action for the next misconception.
Learning through exploration involves the system providing the user with a situation where the learning takes place through freely exploring the material to discover new principles and regularities. The tutor has to select an area new to the learner, set up the environment to allow exploration to take place, monitor progress and provide some form of guidance. An example is WUSOR (Goldstein and Carr, 1977) which uses instructional games to tutor the student. The learning material is disguised as parts of the game so that there is no direct knowledge being conveyed to the student.

Apprenticeship is commonly used by experts to demonstrate a specific skill accompanied by verbal explanations. The apprentice will watch the expert, copy smaller parts of the process until reaching a level of competence when the whole task can be performed. Such an ITS needs to have the capability of being able to reason about the student. This strategy requires the system to use a 'glass box' domain model. SOPHIE (Brown et al., 1975) employs the apprentice strategy as an ITS for trouble-shooting electric circuits. The student is given a simulation of a laboratory and shown demonstrations of a task carried out by an expert, which they themselves are to eventually perform.

Successive refinement is most suitable for tutorial material that contains a large amount of detail. A tutor provides a picture of the domain at a global level and gradually increases the level of detail as the learner progresses. As the detail increases, the tutor has to be able to explain previous oversimplifications of the domain and continually refine the mental model of the domain that the student has at that particular time. STEAMER (Hollan et al., 1984) presents a top level view of a steam plant and as the student progresses, more sophisticated materials are tutored. This is achieved by a hierarchical decomposition of the domain to allow students to explore the lower subsystems of detailed domain knowledge.

Practice appears in the tutoring strategies of many ITSs. The student practices problems generated by the tutor, who in turn provides feedback. The value of this type of activity is that the learner will acquire new knowledge and apply this. The Lisp Tutor (Anderson and Reiser, 1985) provides a lot of practice in basic, recurrent skills in Lisp. It purposely allows the learner to make errors to provide explanations about these.
2.4.6 ITS Research Issues

The discussion of this division of an ITS into three distinct components has added to the assumption that learning knowledge is 'transferred' to the learner from the knowledge contained in the ITS. Therefore the "accumulation model" of learning remains at the core of learning, being found in most forms of computer-based tutoring and training. This is the transfer of information from the teacher to the learner.

The role of the computer, if any, is to test and see whether these facts have been absorbed properly. This would most likely mean an environment in which students receive continual practice, encouraged to speed up knowledge transfer, and continuous testing to determine if the facts have been transferred properly. The student becomes a "storehouse" for facts and correct recall of the facts will be regarded as evidence of successful learning. This approach creates a mismatch between the cognitive theories and the learning-by-doing approaches that underlie ITS and traditional classroom instruction (McKendree et al., 1995). As a result, the educational paradigm portrays a reliance on learning by being told, a principle that is continually being challenged in terms of validity. In providing learning using the discovery learning paradigm this assumption also exists that discovery is about being told what is to be learnt by the teacher (Markle, 1992).

There are also a lack of guidelines in how to develop instruction and learning (Wenger, 1987). This partly stems from a lack of established rigorous findings from educational and cognitive psychology in which to base the design of such tutoring systems. This lack of a commonly agreed upon methodology has slowed the progress of ITSs and many remain as laboratory experiments (McKendree et al., 1995; Nwana, 1990).

Changes have also occurred with the types of domains that are now taught using ITSs. In the past these have tended to be factual domain information such as WHY (Stevens et al., 1982) and SCHOLAR (Carbonell, 1970). But later systems became increasingly focused on tutoring procedural skills such as the Grace Tutor for teaching COBOL programming (Clancy, 1987).
As in traditional Programmed instruction systems, ITSs lack a base of empirical evidence on the effectiveness of these systems for promoting learning. Sleeman and Brown (1982) provide a comprehensive discussion of major ITSs and the successes in areas such as classroom and work settings. A possible reason why there has been a lack of adoption of ITSs into classrooms may be due to failures in technology transfers.

As McKendree et al. (1995) argue, the accumulation model of technology transfer works no better than the accumulation model of learning; those who can select to use the technology are not empty vessels for researchers to "pour" new findings into. Educators and teachers need to be involved as active, valued participants so that they can learn-by-doing, rather than just the users of the systems themselves. Others regard ITSs as still at the laboratory stage (Romiszowski, 1992)

This lack of adoption in the classroom has added to a movement away from educational systems that may not have any intelligence embedded into the tutoring component (Jonassen and Mandl, 1990; Lajoie and Derry, 1990). This is partly due to the inherent difficulties in building ITS components, such as effective user modelling (Elsom-Cook, 1990). A current example of this is the increasing application of hypertext as an environment for promoting learning. This interest has grown with the exponential growth of the world-wide-web, and forms the main research of this thesis.

2.5 Cognitive Tools for Learning

The movement in learning psychology spans behaviourism, based on Skinnerian methodologies, to cognitivist approaches to learning (Sprinthall and Sprinthall, 1990). The principles behind the creation and application of such cognitive tools are discussed below.

Cognitive learning theory portrays the learner as consciously interacting and interpreting the information and then re-organising this information, constructing
personal knowledge representations connected to previous knowledge. Cognitive tools reflect this constructivist approach. These have been referred to as 'mindtools' and allow students, for example, to construct concept maps to explore their understanding of complex knowledge domains (Entwistle, 1992). The ideas behind these techniques relate to Bruner's (1966) modes of representation. With these tools students can alternate between diagrammatic (iconic) representations and text (symbolic), whilst maintaining a level of activity which should evoke a deep approach to learning. Cognitive tools are considered as being different from previous, more traditional systems for teaching (such as programmed instruction and drill-and-practice) in that they are constructivistic and cognivistic.

These tools are constructivistic because learners are encouraged and given responsibility to restructure and try out their theories by comparing them with competing theories. Emphasis in the constructivist approach is placed on discovery and experimentation, with learners applying revised ideas to other situations rather than simply absorbing facts and numerical data (Wiles and Wright, 1997). Therefore the aim is for the learner to construct and in some way, take ownership of models of the information and to relate it to prior knowledge. As Wiles and Wright (1997) argue they must personalise their understanding which is:

"greater through ownership, they are not to be regarded as blank CD-ROM's waiting to be burned!" (pp.29).

Cognitive tools activate and promote the use of cognitive and metacognitive (i.e. learning how to learn) strategies for learning (Draper, 1992). This is achieved by allowing the learner to filter and re-organise the material whereby new knowledge can be related to past knowledge (Jonassen, 1992).

The learner retains control, whereas traditional programmed instruction systems are determined by the teacher and primarily behaviouristic in their view of the learner in the interaction with the learning environment. A short discussion will follow of two types of systems that are regarded as fulfilling the criteria of cognitive tools, firstly hypertext systems and secondly semantic network tools. This is discussed in further
detail in Chapter 5 as the use of hypertext and the conceptual map is as a cognitive tool for the mind (Kommers, Jonassen and Mayes, 1992)

2.5.1 Hypertext for Learning

Hypertext has received increased attention as an educational environment to promote learning. Its ability as a tool for learning will be discussed as it is predominantly used for navigating the World-Wide Web, and a main hypothesis of this project is to examine the efficacy of guided discovery over a free exploratory approach in a hypertext-based web environment. The combination of hypertext with a guided discovery component will be further discussed in Chapter 7 and the implementation of this system will be described in chapter 8.

In terms of ITSs, hypertext systems used for learning are less reliant on the creation of a complete student model in order to provide instructions to the learner. Instead the aim is to provide support for the cognitive requirements of the student. This in turn, makes the methodology for constructing such a system different from a traditional ITS. In terms of computer-based learning, hypertext is perceived as offering learners complete control over the material, this is where its main advantage lies.

An educational strength of hypertext is that learners are able to select their own path through the material to be learnt in a non-linear manner. This is different from previous educational systems such as branching programs, because hypertext emphasises the freedom to explore (Allinson and Hammond, 1989). The main suggestion is that concepts are acquired in a way controlled by the learner. Also, because of the manner that hypertext allows the learner to move from the general to the specific by following links, the learner will acquire an understanding of how the concepts are inter-related, with skilled learners being able to benefit from complete learner control (Steinberg, 1988). Inexperienced learners who have no previous knowledge of the domain will benefit the least from complete learner control because there is a greater likelihood of not knowing what to select next (Kinzie, 1990). Section 5.8.1 carries out a fuller discussion of learner control issues in hypertext.
It is this freedom to explore that allows hypertext to provide conditions suitable for discovery-type learning (Markle, 1992) and also incidental learning. In terms of discovery learning, the learner will find concepts and relationships within the environments which were not previously known. This will lead to the "aha" experience (Bruner, 1974) with the suggestion that discovery of the concepts will lead to greater knowledge than being told the concept.

The move is away from behaviouristic CAI, and towards a learning environment providing varying degrees of freedom and guidance. The potential is for hypertext to support knowledge acquisition through expansion of a learner’s semantic network (Jonassen, 1990). A survey of educationists provided a result that computer-based learning, which includes hypertext, was viewed as being beneficial because it could allow students to learn at their own pace (Laurillard et al., 1993). In terms of hypermedia, a new dynamic form of interactive learning will alter the role of the teacher and the learner (Marchionini, 1990). Such systems can provide guidance via hypothesis generation, testing and exploration (see section 3.6).

In providing such a high level of user control, specific difficulties related to hypertext for learning are encountered. Basic hypertext systems are weak for displaying which hypertext nodes have been visited or giving views of the information at a higher level. They may therefore navigate through the information in a cognitively inefficient manner and the interface may interfere with this exploratory process (Hammond, 1992).

In terms of hypertext systems as a cognitive tool, the use of hypertext for knowledge construction suggests that the process of constructing knowledge can enhance learning. Just providing a route through the information is often not enough to promote learning; there must be an active approach. Passive browsing means that the learner may not engage with the material but instead merely follow the structure that the hypertext designer had pre-determined. In terms of allowing the learner to construct personal meaning, reflection and analysis, hypertext allows the learner to do so to a certain degree. As a constructivistic tool, some systems offer the learner the option of annotating and creating new links to personalise the information space.
although the majority of hypertext systems do not and are made of pre-determined fixed links instead.

Research has also demonstrated that student post-test scores were enhanced by using concept tools alongside hypertext (Reader and Hammond, 1994) providing further evidence that students should be encouraged to use cognitive tools to structure their thoughts. There was a clear position put forward at the NATO ASI workshop on cognitive tools for learning that hypertext can sometimes be considered as a cognitive tool (Jonassen, 1992). The provision of knowledge hypermaps is based on the idea that a hypermedia corpus is a semantic net and therefore it is beneficial to display the corpus as a net on the screen.

Another advantage of using hypertext as a tool for learning is that those who constructed the hypertext system (the authors) learnt the most, such as in the Intermedia system (Beeman et al., 1987). The teachers who helped in the design of the system re-formulated their lessons and incorporated more approaches for helping the student understand the material. Mayes et al. (1993) also found this similar result in the StrathTutor system.

But most hypertext systems still continue to regard the learner as a passive receiver of information from the tutor. Although browsing can bring benefits, these are very limited; with the suggestion that building links and encouraging reflection is more beneficial in promoting learning. Interactivity is also seen as an important part of engaging with the learning material (Jonassen, 1988). Others continue to question the pedagogic abilities of hypertext, and suggest that it is merely an interactive tool for information retrieval rather than one for learning (Duffy and Knuth, 1990).

The suggestion is that a hypertext system which provides exploration does not guarantee that users will learn from it. Students are able to easily miss out specific areas of information, adapt misconceptions due to inappropriate navigational paths and be unsure of the level of progress achieved. Some direction may be necessary for hypertext to be an effective educational tool so that it is perceived to be of benefit by the student (Landow, 1990; Laurillard, 1993). Problems associated with navigation in a hyperdocument of considerable size such as disorientation (Conklin, 1987;
Tompsett, 1989) have led to support for additional tools. Some of these have been search mechanisms, browsers and the option of pre-defining learning paths through a hyperdocument. Therefore the suggestion is that there is a need for more directed support in the exploratory process, with the possible use of AI techniques for providing navigation and advice. However caution must be taken to avoid cognitive overload by including too many tools for the user to learn rather than focusing on the domain material itself (Zao et al., 1993).

In summary, hypertext as an educational tool provides a powerful means for representing knowledge and an effective means of enabling access to that knowledge. The use of hypertext as a cognitive tool remains unproven, as are its benefits for encouraging learning, but it provides a seemingly beneficial approach to learning. Criticisms, however, suggest that there is a need for further research. There remains a need for additional instructional and pedagogical elements. The criticism is that hypertext systems (as with CAI systems generally) focus on the side of being either too passive or too prescriptive in the instruction that they give (Edwards, Powell and Palmer-Brown, 1995). It is the aim of this thesis to examine techniques to guide the learner in forming an understanding of the subject domain, using hypertext implemented with a guided discovery pedagogy.

2.5.2 Semantic Networks

A semantic networking tool can be defined as a set of concepts, or entities, that are inter-related; with the nature of the relation providing further information. The learner is provided with a graphical visual realisation of the concepts and the relation between them. There is usually a spatial dimension to the organisation of the entities with functions such as the labelling of the relationships being made available to the learner. These semantic network tools are originally derived from paper-based concept mapping techniques that are still currently used in classrooms (Novak and Gowin, 1984).

The principle in using the tool is that it can support learning by encouraging learners to examine and investigate the underlying principles and relationships within the material and to structure the concepts to become inter-related. But there may be a
need to allow more than the construction of the semantic network by the learner. The criticism of the use of this tool is that learners have to analyse meanings of the clusters of concepts, which they may have difficulty carrying out, especially if the subject domain is far removed from previous knowledge. The use of other cognitive tools is discussed further in chapter 5, and has been included here as a brief introduction to the theory of the concept mapping tool used in the system in this experiment. Examples of concept maps and how they are built to reflect the underlying hypertext structure are also included in chapter 5.

2.6 The Effects of CAI on Learning

For many, the increased use of information technology is seen as inevitable, as governments examine the benefits of open and distance learning for the support of efficient academic delivery. In the United Kingdom £33.5 million has been invested in initiatives like the Teaching and Learning Technology Programme (TLTP, 1995) and CTI (Computers in Teaching Initiative). Even though the level of activity has grown in the use of CAI in British universities there is still an under-utilisation of the more sophisticated ways in which computers can support learning. Systems that do exist have been found to be less thoroughly evaluated in terms of quantitative data and their claims for gains in learning remain questionable (Wellington, 1995). Section 5.7.4 provides a further discussion of the research methods used in the past for collecting results on hypertext and learning.

Initially computers were used to present information with techniques derived from programmed instruction. These methods appeared to improve students' academic performance and slightly increased a positive attitude towards computers for learning. It markedly reduced the time needed to work through a topic. These teaching methods were used for research purposes but increasingly new instructional techniques are being explored (Entwistle, 1992).

Hypertext and hypermedia have been seen as offering great potential for the area of learning (Oliveria, 1992; Thimbleby, 1992). Despite this support, few teaching staff
develop hypertext applications, the main reason being overly lengthy development times (Elliot et al., 1995). Therefore, although CAI can bring gains for certain types of knowledge, it remains under-utilised. Newer pedagogical approaches for structuring educational systems lack a scientifically proven database of findings and this remains the case for designing WWW hypertext systems to support learning. It is suggested that the work from this project will contribute to guidelines for designing such systems that rely on learner-led exploration of a hypertext environment with the purpose of learning about a specific domain.

2.6.1 Conceptual Framework for CAI

It can be gathered by the evaluation of different CAI systems that they have various strengths and weaknesses in how they support the learning process. Discussion will now centre on the placement of these systems into a coherent framework in order to aid the understanding of their relative merits.

It is suggested that a typology of instructional uses of CAI should be developed. Classification systems, such as Bloom's behavioural objectives (Jones, 1989), is one way of organising systems based on types of learning. Another way is in terms of learner control. Categorisation in terms of learner control allows CAI systems to be subdivided according to this singular characteristic. This is usually in the form of a scale ranging from total system control to learner-led control (Ferguson, 1992). In terms of the systems discussed in this chapter, figure 1 shows how each of the systems sit on the scale.

![CAI Scale in terms of Learner Control](image)

**Figure 1: The CAI Scale in terms of Learner Control (Ferguson, 1992)**

Those systems at the left-most part of the spectrum (those regarded as traditional programmed instruction - linear programs, branching programs, drill-and-practice) are
regarded as directive learning. Here the system retains overall control of the learner’s actions, allowing the acquirement and development of skills in a structured, specific manner. Those on the right-most part of the spectrum (hypertext, cognitive tools) provide an exploratory environment imposing very little system control. This is reminiscent of the spectrum of learning styles that teachers can use in the classroom for organising learning episodes (Mosston and Ashworth, 1994) (see section 4.1). The principle of learner-led interaction is that the exploratory process is governed by what the learner perceives as relevant to achieving a particular goal and the strategies used to find that goal. In order to determine the tools and features to add to a system for learning, there needs to be a question of the type of learning that the system is supposed to support (Mayes et al., 1990).

The scale put forward by Ferguson provides some ideas about how to classify CAI but does not provide a comprehensive overview of other dimensions which differentiate systems. Although Ferguson’s scale highlights various systems suitable for different forms of learning, simply classifying existing systems does not really provide a detailed set of guidelines for the design of new systems. It is more useful to determine the features that could be useful in supporting different types of learning. Therefore, for a full typology to be developed, an analysis has to be carried out on other definitions of learning and pedagogical theories for diverse domains; as well as learning styles and learning activities.

By applying broad-based cognitive theories it is easier to understand how best to utilise hypertext and other flexible learning environments. In order to develop a larger framework, CAI should be examined in terms of competing learning theories or theories of pedagogy (Jones, 1989). Each proposed feature or tool of the system used in this thesis could then be examined in terms of this pedagogy.

Therefore the main aim of this section is that instead of just focusing on building new and better implementations there must also be development of a theoretical framework as to how, when and why hypertext systems (particularly a guided discovery-based version) will be applicable.
To determine the requirements of other CAI systems, Hammond (1989) provides two additional dimensions to user control. This is presented as a three-dimensional view of computer-assisted instruction as shown in figure 2.

Figure 2: A Three Dimensional View of Computer-based Learning (derived from Hammond, 1989)

The first dimension refers to the goal of helping learners structure the material (X axis: generation); the second is the control over sequencing of materials (Y axis: control); the third is the degree to which learners engage with the materials (Z axis: engagement). Hammond does not claim that any one position in this space is better than another; instead the aim is to draw attention to the fact that there is a lack of systematic research to know which is best for learning.

These dimensions will be used to examine the different CAI systems. For each of the three dimensions proposed by Hammond, three points can be distinguished: high, which is the upper right rear quartile (high creative, high active and high student control); low, which is the lower left front quartile (low creative, low active and the system has control) and the midpoint relating to the central part of the spectrum.
In terms of programmed instruction this can be placed in the low part, allowing restricted learner control, objectivistic transfer of knowledge rather than generation by the user, and activity only in answering questions. Hypertext is more directed towards the upper right rear quartile, allowing the learner control, neither providing objectivistic or constructivistic knowledge (acting more as a presentation device) and providing passive engagement in terms of relying on browsing.

2.6.2 Extending the Dimensions of CAI for Guided Discovery Learning

The position of the system constructed for this thesis is to position it towards the upper right rear quartile but with changes to certain aspects of the hypertext. Although a high degree of freedom is required for certain stages of the learner's exploratory behaviour this should be restricted for other times. A basic hypertext system does not provide the active encouragement which is required, but provides a platform for the provision of a CAI that permits exploratory behaviour with a mixture of tutor (system) versus student control.

This structure has been extensively modified in this project to reflect other factors that affect guided discovery specific to WWW, hypertext and learning. Using this system the Z-axis for engagement has been converted to a cylindrical shape composed of inner sections (Figure 4 provides a display of the sections of the cylindrical shape). Hence a revision to Hammond's model is put forward. The revised model is displayed in figure 3 overleaf.

The hypothesis in this experiment is that the discovery aspect of hypertext systems should be retained, but that there is a requirement for a guidance aspect to the learning process.

It is suggested that guided discovery stages will provide more positive engagement with the material for those learners who require this additional cognitive support and that the system will gain control upon detection of inefficient navigation. In offering guidance it is proposed that this type of hypertext system will provide a shift towards the upper right quartile of the axis.
Therefore, the aim of providing guidance is to support learners by structuring the material (X axis: generation), system control over the sequencing of materials (Y axis: control), and high cognitive engagement with the domain materials (Z axis: engagement).
The Z axis is thus depicted as sub-divided into specific areas that need to be taken into account when designing learning systems for the WWW, as illustrated in figure 4.

This figure illustrates that a CAI system can be considered in terms of software (and hardware) factors, factors specific to learning and human factors. It is proposed that the core of the approach for designing a WWW learning system should be the pedagogical factor (in this case, guided discovery learning - GD). And also that the Internet affects all the other issues and that this should not be underestimated. These inner sections are inter-related. The figure is used to draw attention to the issues that should be considered in designing systems for learning on the WWW and that have either been neglected or not been established.

![Diagram](image)

**Figure 4: Specific Design Considerations for WWW Learning systems**

These different issues will be discussed throughout the thesis. Figure 4 is used to highlight the multitude of factors that have been considered in the design of the guided discovery learning environment for this project. It is suggested that guided discovery stages will provide more positive engagement with the material for those learners who require this additional support, and that the system will retain some
control when detecting navigation in an inefficient manner. Although Hammond suggests that no position is better, it is suggested that the shift proposed here is best suited to learning in a WWW hypertext environment.

2.7 Discussion

This chapter has charted the shift from behavioural-based CAI to cognitive-support learning systems such as cognitive tools. Hypertext allows exploratory actions by the learner but is in some sense passive in that the learner can browse without really processing the material. The use of cognitive tools allows the learner to process the material in a more active manner, to become highly engaged cognitively in processing the material. It is suggested that hypertext is a cognitive tool that can promote learning. What are lacking are established educational paradigms for structuring hypertext, as the efficacy of hypertext for learning remains unestablished. Indeed, the cognitive processes involved are in many ways still unexplored, specifically in relation to learning.

The framework that has been proposed in this section posits hypertext in terms of a paradigmatic shift from behavioural to cognitive theories of learning, with a constructivist model of the learning process. In terms of classifying existing systems, cognitive theories are a way of analysing the features used in supporting different types of learning. Using this approach will create a theoretical framework, or arena, for discussing and explaining how best to utilise hypertext on the WWW.

Therefore for a full typology to be developed, an analysis has to be done on other definitions of learning, different educational pedagogues, other subject domains, student learning styles and learning activities. The proposed features and tools of the system used in this project should be examined in terms of the dimensions discussed in this section, with a particular investigation of the sections within the engagement axis. This thesis puts forward the proposition that a hypertext system built using a specific educational approach, will find an ideal compromise between maintaining control over the learner’s exploratory process, whilst preserving the discovery aspect of learning in a guided manner in a WWW hypertext environment.
Chapter Three

Research Issues in Discovery Learning

3.1 Introduction

Discovery learning encompasses many ideas which have been prevalent in education, before the use of the computer as an educational tool. Past research has shown that unguided discovery in learning is in itself insufficient to guarantee that the learner (the human subject who wishes to learn a specific knowledge domain) will encounter and assimilate all of the relevant knowledge and concepts which have to be learnt (Sebrechts and Marsh, 1989; Sussex, Cummings and Cropp, 1994).

From this it can be concluded that if a discovery learning environment is to be implemented in a computer system, the learner cannot be left to explore the material in a completely unstructured and unhindered way. When left alone to explore on the computer, evidence from Jaynes (1989) has shown that the learner will be reluctant to do so. In some cases the learner will not 'discover' the relevant concepts and knowledge in enough depth, or may not encounter it at all.

Guided Discovery Learning forms the main educational pedagogy behind the construction of the guided discovery learning environment. There are three main hypothesis explored in this thesis. The first hypothesis is that a guided discovery learning environment will produce better results than a non-adaptive hypertext environment utilising the Internet. This educational approach will lead to greater gains in learning outcome and equivalent user satisfaction than if it was not included in the system. The second hypothesis is that the combination of other tools will serve to enhance the benefit of this type of educational paradigm further. The inclusion of a
cognitive tool, in this case concept maps, supports the tutoring element. The third hypothesis is that there will be improvements in learning using this guided discovery environment regardless of the different learning styles that the learner possesses. Improvements in learning and satisfaction with the learning episode will be measured in scores from tests on learning outcome (knowledge gains) and user satisfaction questionnaires with interviews.

3.2 The Aim and Organisation of this Chapter

The previous chapter focused on guided discovery in terms of classroom practice and philosophical debate (Chapter 2). The purpose of this chapter is to chart how guided discovery has been utilised in a specifically computing context for teaching. A framework for the discussion of guided discovery teaching styles is given in chapter 4 and the construction of the guided discovery condition is given in chapter 8.

The main purpose of this Chapter is to explain the pedagogical theory for the architecture of the system and slotting it within the framework of educational computer systems. This will highlight the many permutations that the approach can take and draw together common strands or denominators. The two main questions used to structure this section are:

(1) Is there a need for guidance in the discovery process?
(2) If there is, then what form can this take to be effective?

The report is divided into sections following specific themes. This division is flexible as issues are not easily separable and are included when it is seen as relevant and interconnected to other issues. Interface issues are linked to design and also to guidance, so they appear throughout these sections. The first part will be a discussion of discovery learning in a computerised learning environment. The second part of the chapter will focus on issues of guidance, justifying why there is a need for guidance and how this has been implemented. The third part of this chapter will examine the tutorial aspects of the system. The fourth part of this chapter will focus on the design
of guided discovery systems. The final section of this chapter will focus on the combination of guided discovery learning with other cognitive tools. These issues are crucial in designing a guided discovery tutoring environment.

3.3 Definition of Guided Discovery Learning

Emphasis on discovery learning has appealed to educators for many years. The aim is to provide learning that comes through free activity in a rich environment, only weakly moderated by the teacher to facilitate learning.

Guided discovery is a teaching style that engages the student in the discovery process. It moves away from the "reproduction" of knowledge that is often found in the instructor-oriented approach, instead emphasising the "production" of new knowledge.

Guided discovery has at its essence a particular teacher-student interaction in which the teacher's sequences of information and questions cause a corresponding set of responses by the learner. The approach invites the learner to think, and as Bruner (1974) suggests to go beyond the given information and then discover the correct information.

This ongoing process of questioning and answering by the teacher elicits a correct response which is discovered by the learner. The cumulative effect of this converging process leads the learner to the discovery of the sought concept, principle or idea. More succinctly, Bruner (1974) states:

"One encounters repeatedly an expression of faith in the powerful effects that come from permitting the student to put things together for himself, to be his own discoverer".

He goes on further to suggest that:
"I shall operate on the assumption that discovery ... is in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional insight".

These quotes form the basic premise of discovery learning.

3.4 Research issues contained in the Current Literature

The powerful flexibility that multimedia provides (Alty, 1991) and the recent growth of Hypermedia/Multimedia in educational programs suggest the possibility that the teacher can manipulate educational material in a way previously not offered. As these programs are made increasingly accessible via the Internet and used to supplement or even replace classroom contact (Edmonds and Pang, 1995) there is a move towards allowing students the ability to explore the information in a non-sequential and less prescribed manner. This extension of the learning environment away from the traditional teacher-student scenario suggests a change in both the role of the teacher and the limits of the classroom boundary.

The history of education suggests that this is far from the first time that optimistic support for discovery learning as the dominant pedagogical strategy has surfaced (Jacobs, 1992). This time the support for a guided discovery approach to learning has been fuelled by the inherent flexibility of hypertext (Woodhead, 1991), and more recently, hypermedia and virtual reality as prominent components for future educational applications.

With the increasing power and extremely rapid growth of the Internet and the popularity of World Wide Web (WWW) graphical browsers such as Netscape and Internet Explorer, hypertext and the WWW will play an enormous part in education in the future. Chapter 6 examines this concept of online learning; and its implications for learning environments and tutoring systems that utilise the Internet.
This in turn suggests that discovery learning will grow in parallel. The increasing popularity of the WWW where the development of increasingly simple to use browsers furthers the ease of exploring or 'surfing' the Internet. With this is the ethos that there are resources to be discovered on the Internet and that they can be placed on the web with the learner carrying out the learning in a self-exploratory and independent fashion.

What is discussed in this section are issues which have been investigated in the past and how these can, in turn, be used to contribute to other topics in the future. The discovery learning paradigm has been promoted as an approach to designing a learning environment using technology previously unavailable. But what needs to be addressed is not only how discovery learning can be implemented but also how the designer can find a balance between providing discovery and giving guidance.

3.4.1 A Brief History of Discovery Learning

In the history of education there has been a long rejection of teaching based on discovery, exploration and individual experience. But there has been increasing support for a qualitatively different way of perceiving the education process by many educationists. The change in view of the teacher becoming a facilitator of information, rather than just a conveyer of it, has encouraged the idea that learning by discovery is the most effective type. For a historical perspective of discovery learning Jacobs (1992) and Markle (1992) provide a fuller discussion of the following proponents of this educational approach.

Socrates is the earliest example of a teacher supporting discovery learning. The lesson is of an ignorant slaveboy who is made to discover for himself the validity of a rule of geometry (this is discussed in section 3.5.2). Comenius in the seventeenth century emphasised the precept that students need to arrive at the truth for themselves based on their own experiences and following their own paths.

Locke in 1894 advocated the use of sound and images to help provide an experiential learning process, whereby this is built upon the learners curiosity. This support for learners determining their own educational paths was reflected again in the eighteenth
century whereby in 1762 Rousseau argued that formal teaching destroyed curiosity. Instead this should be encouraged and the child should be allowed to learn by observation and discovery. In the 1850s a direct supporter of Rousseau, Pestalozzi, cited the freedom of the learner to develop skills and knowledge as the centre of an approach to learning. The premise was that learning starts with experience and that the teachers function was to guide the learner through the education process itself by making the learner actively engage in exploring the material; to think rather than just absorbing knowledge. The theory which Pestalozzi put forward resembled the basic premise of interactive multimedia.

In the nineteenth century other educationists promoted the idea of discovery learning. Whitehead (1929) emphasised the discovery aspect more. The purpose of education was to stimulate and guide the student to experience the joy of discovery, not to fill them with ideas which were accepted without being used, tested or formulated into new combinations. Dewey in 1938 was the most important figure in this period. He viewed academic discipline as summaries of human knowledge and therefore learners should approach this by summarising their own experiences.

In practice, however, there was very little practical application of discovery learning. Teachers have mostly rejected the theories of educationists such as Locke, Pestalozzi and Whitehead. Many of these educationists in the twentieth century who had promoted the virtues of exploiting the learner's curiosity have either been suppressed or ignored. There was continued strong support for the tradition of rigid instruction based on the imparting of knowledge by teachers, thus it could be seen that twentieth century attitudes reflect those found in previous centuries. But in the latter half of this century there was the introduction of a new factor, the growth of unparalleled leaps in technology both in accessing and manipulating information.

By the early 1980s desktop computers offered significant advances on Skinner's teaching machines by opening up possibilities for non-sequential instruction (Ostrovsky et al., 1991). Papert (1980) recognised this potential in Mindstorms (1980) where children should be given control to allow self-directed learning to occur spontaneously.
But this shift towards another paradigm is not as new as it initially seems to be portrayed by others (Jacobs, 1992). Researchers continue to draw contrasts between the old and new approaches to learning. McGill and Weil (1989) talk about a shift from the linear logic in the past to the lateral thinking of the present. There has been the introduction of new metaphors such as webs, tapestries and spirals to represent knowledge. The new paradigm is one of emphasising wholeness through interconnectedness and interdependence. This has been further fuelled by the attractions of new technology and especially hypertext.

One of the main features of hypertext is the ability to allow the learner to move in a non-sequential way through a conceptual information space, with the claim that the learner will learn 'incidentally' while exploring it. The move is away from the task oriented, programmed teaching type of learning environment and with this the image of the student as a receptacle for the knowledge and experience of the teacher. Instead learning is by discovery and personal experience; to follow paths according to intuition and browsing. This could be regarded as an integration of several concepts and technologies. On the one hand there is the perception of education as a non-linear process and on the other hand there is the integration of text, images and sound in the form of multimedia.

In the past hypertext was discussed but was not implementable due to limitations in hardware and software constraints. Nelson (1965) first defined the term as a means of describing a semantic network of knowledge. It is only recently that interactive technologies provide tools which are usable enough for those who want to support learning through exploration and guesswork. Throughout history there has been support for discovery learning but it has never really been widely implemented within classroom practice, with the result being a return to traditional teaching methods whenever there were attempts to incur change.

But computer-assisted instruction still tended to be heavily structured towards the programmed type and seemed to replicate the history of educational practice. This approach remains especially appealing because it is a tool which can determine the rate that the learner progresses, but the drill and practice of programmed instruction has rarely been favoured by the learner. Therefore the next section will evaluate
criticisms of discovery learning and the implications that increases in the capability of computer technology have for discovery learning.

3.4.2 Criticisms of Discovery Learning

A symposium devoted to discovery learning (Shulman and Keislar, 1966) did not give it unanimous support, at least not without many qualifications. The general orientation of discovery learning is clear enough: the subject finds out something using self-selection, especially some generalisation or principle, without it being explained initially to the learner. Usually the learner is afterwards given the task of explaining the material to the human teacher in a different form to determine whether it has been acceptably understood. But arguments against a reliance on discovery are chiefly twofold.

The first is that one of the main roles of education is the transmission of culture, and that this cannot be left to the use of free discovery alone. This is not discussed any further here as it is not a main part of the research hypotheses but it is included as part of the characteristic of a model of the guided discovery teaching style (Mosston and Ashworth, 1986, 1990).

Secondly, although discovery can aid some of the steps of learning about a topic, it would be inefficient to use this as the only method to employ when learning the topic (Cronbach, 1966). For example in Physics it cannot be expected that the learner will rediscover all the available laws that other physicists such as Newton and Einstein had done decades before. While no supporter of discovery learning expects this to happen, such an example highlights the need for careful specification of the limits of the discovery which can be expected. The student may understand some elementary principles by designing a few experiments and observing the results but the main way of learning should be to study what others have already found out.

Piaget (1957) provides a more structured outline of discovery learning in these terms. He suggests that once the learner has reached the higher stages of intellectual developments, the learner can be an inquirer by studying the experiments of others. Piaget is more concerned with the early stages of cognitive development, and that the
learner should be allowed a high degree of freedom to enjoy discovery. This will reinforce confidence in the child's self-perception as being a problem-solver.

It is suggested, however, that if the teacher does not intervene by rearranging the material, then the user may be frustrated by not discovering the important concept or principle, leading to frustration and de-motivation (Kagan, 1966). It could be argued that Piaget himself did not believe that educational practices could be developed deductively from his theories, but that pedagogy should be studied in conjunction with psychology. The relevance here is that his view of discovery learning has been built on by other theorists who have extended this to support the guided discovery approach.

Discovery learning, as the main pedagogy for learning, has been implemented in the design of early exploratory environments and simulations. Criticisms related to the discovery paradigm for being able to promote learning, have also surfaced in these types of CAI. The support is for an added component, that of guidance, to overcome some of these weaknesses whilst still retaining the benefits which discovery learning brings as a learning strategy. In this case this thesis suggests that it should be applied to using the Internet as a teaching medium. Discovery by itself is not enough. The following section will explain why there has been a need to add guidance to the discovery paradigm.

3.4.3 Discovery Issues which Need to be Resolved for Using New Technologies

There are clearly discernible differences between the computer technology used in the past and the emerging hypertext technology of today. The main attraction of hypertext is that it can be designed to support non-sequential educational approaches. The design of a hypertext environment is one able to encourage free-association (regarded as characteristic of human thought) whereby learners can ideally choose their own direction through the information, exploring what is relevant. This emerging technology will hopefully create a change in long established methods of teaching and create a shift from the teacher as the expert. But history seems to suggest that this change will not occur.
Several difficulties exist in incorporating discovery learning into computer environments and these need to be resolved before the potential of this paradigm can be realised. The value of hypertext for learning and the issue of user control will be discussed next.

At present there is disagreement and uncertainty about the precise value of the new tools for being able to carry out exploratory learning. The majority of those who support discovery type learning environments assume that being 'lost in hyperspace' is a fundamental obstacle to exploration by hypertext tools (Conklin, 1987; Edwards and Hardman, 1989; Nielsen, 1990). But others argue that getting lost is desirable because it is part of the process of structuring information (Mayes, 1990).

This lack of established ideas concerning discovery learning and hypertext can also be seen in discussions about the process of browsing. There remains ambivalence about its value in the learning strategy, even though browsing is an essential part of the hypertext concept. There is not even general agreement on where hypertext tools may eventually fit into the educational environment. There is some empirical evidence derived from a classical experiment by Pask and Scott (1972) which suggests that learners will choose their own best learning strategies if conditions are planned in advance.

There is an increasing amount of research which contradicts the above view, instead suggesting that learners generally tend not to choose wisely when confronted with learner controlled systems (Jonassen, 1990). Others do not even regard this issue of user choice as essential. Jaynes (1989) argues that many learners do not have the time or interest to explore the domain, and want to be led (this is further discussed in the section 3.5.2 on guidance and design). Jacobs (1992) found this to be prevalent in many of the learner-autonomous teaching methods in higher education. It is argued by Jacobs that until these issues are resolved, hypertext tools, which can provide the best resource for implementing discovery leaning, will not be widely accepted in educational environments.

All these issues are open to further research and past work related to this will be examined further in this thesis. The properties which hypertext offers for learning
should be appraised in order to determine how it could be used to provide a discovery learning environment. There is now a consideration of how such systems have tried to integrate discovery learning.

3.5 Issues of Guidance

The degree of guidance and the way that this should occur is a major area of contention. Many of those systems supporting a more exploratory/discovery paradigm have used a varying degree of both structuring and discovery in their tutoring. The issue of selecting between a structured, linear approach and a purely discovery learning environment remains unresolved. Guidance could be regarded as a form of system control; therefore how much control should the system have? Also how can the learner be guided or led to the specific knowledge to be learnt?

3.5.1 The Case against Browsing

Browsing whereby the learner is engaged in just freely exploring a database of material (not necessarily hypertext documents) suffers from several criticisms. There is no clear explanation of how browsing and manipulating variables in the domain will necessarily lead learners to understand the relationship of the factors that have led to the outcome. The absence of an expert system component will not ensure that the learner will follow a particular path through the material. The lack of a student modelling component will result in little adaptation of the material to a learner’s needs, and no testing of knowledge will mean less feedback on progress. A reliance on classroom discussion to overcome these weaknesses and to clarify any confusion is not a guarantee that the learner will understand the material (Bergeron and Paquette, 1990). Therefore a learner may follow stages of discovery moving from free exploration to structured exploration using discovery alone; but a system relying on browsing does not purposefully do this. This is discovery without the guidance. Sebrechts and Marsh (1989) concluded that discovery on its own is not as effective as using a guided component.
Their empirical study into the instructional strategies of both discovery learning and model-based instruction reported limitations in both these approaches for computer-based learning. Pure discovery in which the learner self-explores the computer system may not provide an adequate means for self-evaluation of levels of knowledge and progression. The data by Sebrechts and Marsh showed that discovery learning was less effective as a strategy than interactive problem solving. The learner does not know what is appropriate exploration, nor is the learner aware of the adequacy of what has been learnt. There is insufficient identification of what the problem is, hence there is no gauge on whether the explanation discovered is in-depth enough. Therefore Sebrechts and Marsh summarise that there is a need to focus on how such discovery can be “guided”. The value of adding a guided component to discovery has been replicated by the work of Dong and Wang (1990) whereby the system would give continuous feedback about particular aspects to help overcome misconceptions. The student still retained some freedom in problem-solving strategy and would have the added reassurance of knowing that the answer reached had been validated by the system, as it had guided them to the solution.

Discovery has been shown to have advantages over other instructional strategies. The discovery process has been analysed with a discussion of how environments can provide discovery to take place. With hypothesis generation and testing, Socratic dialogue and experimentation, these can provide some possible ways to design such an environment. What is apparent is that although browsing provides gains in learning; an over-reliance on this as the only instructional strategy provides too much emphasis on the learner’s ability to know what to do. The next section will show ways that a discovery-based learning system can provide this guidance.

3.5.2 How Much Guidance should there be?

Research by Sussex, Cummings and Cropp (1994) suggests that learning should not be through unguided discovery but instead that there is a need for some type of guidance in the learning process. In their design of Mayday (a learning environment for lexical learning) the notion is of exploratory learning. No exploration system is complete in that there is no finite data set or finite pathways through the domain to be learnt. Therefore to allow the user to investigate in a non-structured and flexible way
the software should be left open-ended with tools to explore the knowledge. The tools, which allow the knowledge to be presented in many forms, were structured in such a way as to facilitate creative exploration.

Work by de Jong (1992) suggests that there is a need for a guidance component in systems which claim to support discovery learning. Exploratory learning in computer simulations provides the ability to fulfil the learners' requirement, to freely interact with the model which is to be learnt. However even in an interactive simulation, unguided exploration does not provide the optimum learning approach and there remains a need to provide subsequent support to aid learning.

As Ostrovsky et al. (1991) argues, there is a need for the student to explore, play and enjoy on their own in much the same way as if they were, for example, in a real laboratory with the minimum amount of supervision available. But the findings from the study also recognised that it was unfair and unrealistic to let new learners 'discover' on their own. The solution offered was to provide a structured exploration base which is able to guide the user to a certain degree.

Ostrovsky et al. used a set of cues to help guide the learner through the knowledge domain to be learnt. The aim is to answer any questions which the user may have, to also resolve any misconceptions about the knowledge to be learnt and eventually lead to personalised student discoveries. Cues can be added and made more mutually reinforcing as well as gradually withdrawn to suit the learner. As the student becomes accustomed to the display, the program can allow the user to carry out the discovery process independently e.g. by removing commands from obvious buttons and transferring them to pull down menus. At the same time the system can introduce new resources with more buttons and also turn off some cues. As the user reaches deeper levels of exploration this will result in the gradual removal of cues until the activation of other ones so that guidance varies according to the growing experience of the learner.

de Jong (1992) provides further details of the types of guidance which the system may use to structure and guide the interaction. There are two types of guidance:
1. directive - whereby the learner is steered towards a certain direction. This maybe done by providing the learner with direct feedback or hints for the direction to follow.

2. non-directive - when the learner is not steered in a specific direction but instead is given some help with accomplishing what would have been done in a completely free exploratory environment.

In the SIMULATE Project (de Jong, 1992) the basic functionality of the interface offers non-directive support. In future Intelligent Support Learning Environment (ISLE) the interface should incorporate more directive support, for example by displaying system messages, which can guide the learner or give hints on what to do next (Towne et al, 1990). The suggestion is that for learning, there should be a mixture of both types of guidance to guide the user towards the desired knowledge to be learnt.

But there is disagreement over how achievable discovery learning can be and whether the user can learn in this type of educational environment. Teaching using discovery has had a long history of claims about the emotional and intellectual advantages that it offers over traditional CAI. But there are very few systems which have an actual design which facilitates discovery learning (Markle, 1992).

Markle provides evidence that Socratic dialogue, which is cited as the source for much of the early ideas tied to discovery learning, (Jacobs, 1992) does not necessarily reflect discovery-based learning and is not even a good example of the types of questioning which is required for this type of learning environment.

Markle claims that the Socratic method prevents “true” discovery by not allowing the learner to admit when there is misunderstanding. The Socratic lesson is that whereby the 'slaveboy' (regarded as the student) replies “yes master” to the question just posed by Socrates of “you do understand?”. The question which Socrates had asked had been formulated in such a way that the slave boy was not given the option of any other reply. The slave boy is pressurised into not revealing any misunderstanding but to accept that Socrates has presented the knowledge and that it is the slaveboy who should automatically understand. The criticism is that the model of instruction used is
inductive. Markle argues that generations of students have done the same, following a line of questions presented by the teacher and replying yes to the expected reply. Therefore although learners may reply that they understand a concept or area of the subject domain; it should not be assumed that this is valid. The learner needs to be tested.

There needs to be an examination of the circumstances in which a learner 'discovers'. Designers who implement hypertext need to question what it means to discover while being told. How much should the learner be 'led' to the correct answer? Discovery is not only concerned with guiding a learner to find a fact, or to locate a certain piece of domain knowledge. These are outcomes which a learner can achieve without guidance from a teacher and which can be found unintentionally by just looking through a book. But Markle (1992) views discovery as being more than locating the correct section of knowledge. Instead it is being able to provide higher levels of learning e.g. the creation of classification schemes, the workings of rule-based systems and the learning of useful strategies. The emphasis is on the need for guidance during the discovery process. The suggestion is that just guiding the user to the domain knowledge is not all that is needed. That exposure to the relevant material is not enough.

There needs to be an examination of how the user can use this knowledge rather than just being exposed to it. There needs to be an establishment of a 'middle ground' between what Markle argues is 'traditional educational professor-controlled telling' and allowing the student to explore in an unfettered way, with no help or sense of what is to be discovered. Results from this should help to determine what type of guidance the learner needs and when it is to be given. Hypertext allows designers to incorporate control, in terms of guidance, into the discovery process.

In terms of varying control in the guidance, the suggestion is to use the tutorial style of “decreasing intervention” (Peters, 1966). At the start of using an unfamiliar system, the user is hindered in learning by having to operate in a subject domain using an interface with no previous experience of either (see section 3.7.2 for Interface issues). Therefore the need at this particular point is for a system tutor which provides a high level of structure to control the interaction. In the final state the
learner should require no help in knowing how to operate within the interface and the environment. The tutor, while initially directing the interaction, must be continually assessing the value of the current learning style and determine whether there should be less control; assessing whether to decrease the level of tutorial intervention (Spensley et al., 1990).

Therefore as the learner works through the material, the system reduces the amount of guidance given; such as the gradual withdrawal of instructional cues (see chapter 8) as the learner becomes more proficient in understanding the material (Ostrovsky et al., 1991), eventually shifting full control to the learner. This may seem to clash with the idea of discovery learning whereby the learner is free to explore the domain at the exploratory phase of the discovery process. But it could be argued that if there was no instruction or restrictions of possible user actions imposed at the beginning, then the naive learner would not know how to begin the exploratory phase.

3.6 The Use of Hypertext

Hypertext and multimedia have been seen as a cornerstone of the method for realising discovery learning. In science education the combining of hypertext and guided discovery is seen as particularly desirable (Costa Pereira, 1992) with the acquisition and subsequent practice of problem solving skills by learners being regarded as increasingly important in subject areas such as Physics and Chemistry. Hypertext and hypermedia allow science education to concentrate on an exploratory approach. Both support browsing in a linear and non-linear mode, and are inherently well suited to discovery learning (Landow, 1992). But there is a requirement for guidance within hypertext itself. This is discussed briefly here as hypertext has been used as an exploratory discovery environment, but it receives more detailed attention in chapter 5, Research Issues for Hypertext.

The ability for hypertext to provide individualised instruction stems from the ability to embed an intelligent tutoring component alongside the hypertext. Megarry (1992) proposes that hypermedia should use additional support material that will structure
exploration and allow students to create fresh combinations and links. Lee (1994) suggests that there should be a combination of multimedia, CBI (computer-based instruction) and expert system approaches. Hypertext is able to retrieve answers to questions very quickly and, when coupled with multimedia, play digitised images with sound to re-inforce the learning. CBI can incorporate instructional design techniques and utilise student assessment to gauge the learner's progress. The role of the expert system would be to provide the specialist knowledge and experience needed to form the domain information. Megarry also prefers the idea of providing guidance in the linking mechanism, proposing that hypermedia requires support material which will help to structure the learners' exploration. In terms of user modifiability the learner should be allowed to create new combinations and links in the material to be learnt. The move has been to structure hypertext at the node-link level. In his book on Hypertext, Woodhead (1991) discusses discovery learning and hypertext. Hypertext should be designed to guide the learner to follow particular concepts and 'pathways' through the material using structured linking. Therefore past research has cited the need for some form of guidance, or structure in hypertext for learning, and that components from ITSs can be used to do so. The emphasis is on a constructive approach with the learner personalising the information space and the system restricting the navigation within that space.

Markle (1992) predicts the growth of an undesirable practice caused by the attraction of hypertext, due to its appeal as a flexible and powerful tool for supporting learning. Lecturers (or Professors as he seems to emphasise) seem to have made hypertext their preferred medium. They are now able to transfer all their words into hypertext and with this is the expectation that the pupil will learn all the material. They regard it as a solution to 'teaching' and continue to believe that anything that is told, either in hypertext or written form, will be learned. But this is rarely the case. This assumption could be said to have been transferred to the web and learning whereby lecturers create web pages of learning material translated straight from word processed lecture notes (see chapter 7 for examples of this).

Lecturers talk about developing students' thinking and problem-solving skills but the old domineering 'talk/chalk' habits are seen by Markle as too easily transferable not only to hypermedia or text-based media but also to visual media (e.g. film, television).
This change in teaching will affect the expectations of both the students and the teachers; since the students may no longer have lectures they cannot easily ask for further explanations and the lecturer may not be able to adapt the notes to suit particular pupils. Telling is not the same as learning and to be able to 'unchain the slaves' (Markle, 1992) there should be a move away from what others supposedly claim is discovery learning, to actually use methods that promote higher levels of mental functions.

With the rapid growth of the Internet the use of hypertext as an instructional medium will increase (see chapter 7). The assumption that discovery learning, coupled with hypertext web pages, will automatically facilitate meaningful learning has grown with this.

As this section has shown, hypertext is appealing as a teaching tool because it allows user control for discovery learning. But there is a requirement for guidance and there remains a lack of design guidelines to implement this.

3.7 Issues of Design

The issue of design in this report is to examine the type of learning goal the system is supposed to teach and how the learning environment has been adapted to attempt to focus and maximise this. There needs to be an assessment of whether the design fulfils the purpose of what the designer or teacher intended and the possible areas of future research which arise from this. What needs to be ascertained is how the discovery-based system has been designed to encourage discovery learning to take place.

3.7.1 Types of Design used in the Past

In the initial stages of design it should be clear what learning outcome the learning environment is aimed at supporting (Woodhead, 1991). Is the purpose to support the teaching of new skills, or to directly encourage the use of existing skills? This will
influence the degree of guidance needed and the form that it will take. It also has implications for interface design as well as issues of user control and the freedom to modify the learning material. In contrast to computer-assisted instruction programs, exploratory learning environments are supposed to offer the learner possibilities which go beyond the capabilities of a human teacher. The discovery in these CAI systems was carried out by: (1) an exploration of a database in a learner-controlled fashion, (2) manipulating variables resembling real-life situations to increase the transferability of metacognitive skills.

Not much is known about the learning processes which take place during exploration (Katz and Lesgold, 1990). Lee (1994) designed the Urological Clinical Tutor (UCT) with two goals: to encourage discovery learning with peer discussion, and to allow the teachers to exploit existing technology in their teaching. The aim was to enhance investigatory problem-solving skills by allowing students to interact with a knowledge base containing descriptions of urological diseases. The UCT was designed to closely model the real doctor’s clinical procedure. The students would collaborate to solve the problem task with the teacher being available to provide fuller explanations. The system was not designed for individualised coaching only, which is what most ITSs seem to emphasise. Therefore by reflecting real life practice into the design, the educational environment becomes less removed from current working practice.

Designing the discovery environment to mimic real life practice was also carried out in Ostrovsky et al. (1991) research on guided discovery and simulations. The aim was to give students an experience of working in a fashion analogous to the procedures of laboratory scientists. In this case the domain was the modelling of liquid water. The simulations were designed to form interactive guided lessons and copied the investigatory practices of scientists. This suggests that it may be easier to transfer skills out of the classroom, as well as less difficult to initially acquire the skills.

In terms of establishing guidelines for design, there are some general principles that could be used for designing discovery learning CAI environments. The aim of the Core Learning Environment for Modula 2 (CLEM), by Boyle et al. (1994) was to teach a completely new topic to students, programming in Modula 2. The requirement was for CLEM to provide the bulk of the teaching and was implemented
in a hypertext tool called Guide. There was a need to search for guidelines to design a guided discovery learning environment. Much research was incorporated into the design stage of the system because the software was to be a dominant part of the overall teaching in that module. Findings from research into natural language learning and cognitive development was used to develop a more 'natural' environment for learning to program.

The design features of CLEM were based on the CORE approach (Context, Objects, Refinement, Expression) which provided a set of principles for constructing a guided discovery learning environment. There were several guidelines in the CORE approach which determined how new learning material was to be introduced and how it was to be manipulated by the user in order to facilitate effective learning and problem-solving. In the introductory phase each new construct or skill was to be introduced in a working context. For example the programs used to learn from consisted of fully working code which the learner already had familiarity with, and the new constructs were highlighted within the program frame. The aim was to provide the learner with an orientation which would support them in fitting the components of the newly acquired knowledge into a context of use.

Another design guideline was that individual constructs and skills were introduced using examples rather than formal definitions. The issue then becomes one of choosing the appropriate examples to aid the understanding of concepts and abstract rules. It has been found that students pay more attention to the examples presented to them rather than the formal descriptive material which they receive in lectures (Segal and Ahmad, 1993).

In the CORE approach it was also suggested that there should be the ability to test the learning. The student should explicitly express the new skill or knowledge which has been discovered. The inclusion of an expression phase can be used to ascertain the adequacy of the student's knowledge representation. This is carried out by having the student complete a project at the end of each section (usually in the form of a program). The feedback is in the form of solutions that are not definitive model answers but instead are examples of good programming practices. Again the emphasis seems to be on the student studying the examples and deducing what the
solution requires. This is preceded by an on-line test composed of multiple choice questions.

Therefore the CORE approach takes the learner through the whole process of discovery learning. From the initial introduction of the new material to be learnt, to the testing of the knowledge. Selecting the type of examples used will therefore affect how the user works through the material actively. How these examples can be linked to allow the user to progressively move from initially encountering the material, to understanding the underlying concepts and finally to applying this new knowledge.

Sussex, Cummings and Cropp (1994) designed their Mayday learning environment in such a way as to examine several facets of discovery learning. From investigating the types of tools that would allow the user to approach the information from different viewpoints, to the role of the teacher in this type of educational environment.

The Mayday project was used to examine whether there was evidence of a decoupling between the Task level (TL - the narrow context of the current learning activity) and the discussion level (DL - the more teacher-directed guidance and advice given before the learner resumes the task). It is claimed that this resembles classroom interaction, whereby the teacher is able to give advice without having to be aware of where the pupil has progressed in terms of completing the specified task or of what is previously known.

The design was strongly influenced by the need to provide features resembling actions of the teacher in the classroom. The teacher would approach the introduction of new knowledge, and the tackling of conceptual misunderstandings, in a non-linear (non-alphabetical) way. By including in the system the functionality of exploratory tools the learner can use similar ways to 'discover' by receiving explanations as if in a classroom. The key to effective learning in a partly unstructured discovery-based environment is in the way that tools and activities are designed to present the domain material, and the subsequent options the learner is given to manipulate them. Therefore the learner does not have to 'wade' through masses of irrelevant information. Therefore the issue is to determine the type of design these tools, for
manipulating the material, should take and what activities can be used to aid the discovery process.

There is also the requirement to try to reduce cognitive overload that the learner may experience in investigating the domain. Sussex, Cumming and Cropp (1994) argue that coursework may not reflect everyday principles and that the lessons may not directly address student misconceptions, instead distracting learners from what should be understood. This can be seen in Physics courses that concentrate students on the need to collect copious amounts of numerical detail mostly for data collection and presentation, rather than focusing on principles and concepts. The design of microcomputer-based laboratory tools by Sussex, Cumming and Cropp, were intended to ease this task of collection and presentation. It is suggested that by allowing the system to collect and process some aspects of the data, the learner is free to concentrate on actually understanding the concepts which lie behind the detail. By using the guided discovery tutoring system to carry out most of the detailed, numerical work the student has to worry less about this. Furthermore because they are guided to ask and answer their own questions students are encouraged to become active participants in the scientific process. Learning is enhanced when students are able to construct the knowledge for themselves (Bruner, 1974).

Immediate feedback is also given when carrying out learner-controlled explorations and when using measurement tools. This is usually presented graphically in graphs and tables which give overall summaries and generalisations. Sussex et al. (1994) cited several significant problems of using data manipulation tools, related to interface design. If there is too much new information at once and not enough mental space to re-organise this information, information overload can occur. Tools can be used to filter out unnecessary information and provide a very specific view into the domain knowledge.

The result was that students showed substantial improvements in their learning of concepts in a Microcomputer Based Learning (MBL) lab in comparison to an ordinary lab. Some simple concepts were regarded as not amenable to lecturing and were only retained in memory until at least the final exam. Overall when using MBL tools, students who ranged from the well prepared, to the badly prepared and ambivalent
showed enthusiasm towards the subject domain. This could be seen to suggest that
the MBL tools are able to promote a positive learning attitude by encouraging
motivation when faced with reluctance to learn a topic.

The need to reduce cognitive overload for the user was incorporated into the design of
CLEM (Boyle et al., 1994). In this case a notebook had been included in the system
to allow the student to type in comments. Related to this was a key design aim of
attaining overall simplicity and to provide intuitive ease of use, which would in turn
reduce cognitive load. Other features contributed to this. The use of familiar
metaphors, especially the addition of an electronic workbook, meant that each chapter
followed a similar structural pattern resulting in consistent patterns of use. This led to
positive feedback whereby students reported having very few difficulties learning
how to use the system.

With the rapid growth of the Internet, the use of hypertext will increase, along with
the assumption that it will automatically facilitate meaningful learning (Markle, 1992;
Watkins, 1992). Some of the findings from discovery learning environments, that
may not be hypertext, can still provide clues about how to design WWW learning
systems. In using discovery learning for CAI, it should be considered that any type of
CAI is part of a wider curriculum and should therefore be planned with reference to
the organisational setting and learner resources (Boyle et al., 1994). Therefore the
design should not only be concerned with the interaction between the user and the
system; but also the wider context in which the system is being used. This is discussed
further in chapter 6, which examines the place of an online learning environment in
terms of distance learning and the ‘virtual university’. The discussion on design has
examined ways that systems have enabled discovery to take place, the next section
will consider specific interface design issues for discovery learning.

3.7.2 Issues of Interface Design

The function of the interface is to present the learning environment to the learner but
its influence has often been undervalued and underestimated. The interface can
determine whether any system, including a discovery-based system, can be used
successfully by the learner.
What the user sees, hears or does with the interface shapes the learner’s model of the system and of the domain being taught. If the interface does not reflect the functionality needed to explore the subject domain, it will hinder learning (O'Malley, 1990). Therefore the issue is to make the interface as effective, supportive and intuitive as possible: effective in that the learner understands the domain at a deeper level of meaning, supportive because the interface should aid the learner whenever there is a requirement for more complex help, and intuitive so that the user does not have to learn the interface first to be able to learn the knowledge domain afterwards (Reimann, 1992). This is a problem more apparent for designing icons, as icons not only refer to the domain semantics but also represent the functionality of the underlying system. Therefore if icons are to be used in a discovery environment, precautions should be taken so that they do not hinder the learning process.

Research has attempted to provide guidelines for designing iconic interfaces (Gittens, 1986; Lansdale, 1988) but the findings are often limited and difficult to apply. This is especially apparent when constructing an interface able to cope with the rich and diverse functionality needed for a discovery learning environment. For novice users of discovery learning environments a specific interface issue is how to represent the functionality of the system so that it becomes either ‘obvious’, or at least easily learnable.

So an issue concerns how to make the user aware of what is available: to be able to design an icon able to guide the user when lost or when unsure of where to explore next. There are other areas of interface design which can affect interaction in a manner previously unanticipated. For example, the metaphor used for the interface design may carry more meaning than the designer may be aware of (O'Malley, 1990).

The interface is the only way the user can operate in the represented world. For the purpose of learning, the interface should in some sense be the represented world or the domain to be learnt. The interface when made transparent should no longer exist for the user in that it should become cognitively directly present. Using direct manipulation affects how transparent the interface becomes. There needs to be recognition of where the boundary of the ‘user-computer interface’ is for the designer.
of the tutoring component of the system. There is an implicit understanding of what is meant by the interface but this needs to encompass more than merely the visual display, the software/hardware platform and the social context in which the system operates. O'Malley considers the user-computer interface as a distributed system. Partly being represented in the user's mind whereby the user constructs a model of the system during interaction. And also being taken in a broader sense to include the functionality of the software, the graphical objects on the screen and even the documentation which accompanies the system.

Deciding the location of boundaries has crucial importance for the possibility of modelling the students understanding of the domain. As Wenger (1988) argues, the interface uses the:

"students ability to read more into its presentations than the system is aware of".

The learner may have a model of the system which may not accord with what the designer had in mind. Therefore interface design is distributed from the low level to the high level, and during construction of an interface all the levels should be considered.

But some graphical (iconic) interfaces provide a very indirect mapping between user goals and the tasks needed to perform to reach those goals. For example some information retrieval tasks are better suited to command-based interaction. There are also possible margins of error in using input from mouse or joy-stick as physical actions have their own syntax. Therefore the issue of affordance also needs to be considered in interface design in a guided discovery environment using direct manipulation. If the user is unsure of what to do, how can the starting point be made more obvious? There is a lack of research on how to execute the functions which the icons represent. For example in the Apple Macintosh there are different syntactic expressions for interaction with the icons, but none of these expressions is explicitly represented at the interface. Some operations need a single click to begin while others need several depending on the context. The mapping of mouse clicks and the subsequent effect of these actions were regarded by O'Malley (1990) as totally arbitrary decisions taken by the system designers.
The problem of fairly arbitrary mapping is more acute when cursors can represent multiple functions or states at one time (Muller, 1988). The mapping between user input and resulting actions are not simply a matter of syntax (ease of expression) but is also dependent on semantics (the naturalness of the expression) and pragmatics.

Representations in other modalities can be used to overcome limitations of the input device. In ARK (Smith, 1986) the input is via a three button mouse-operated cursor represented as a hand. The hand can give feedback by 'opening' or 'closing' depending on whether it is grasping an object. It can pick up, throw and press as well as other functions. But there is still a need to learn how the interface operates as the mapping from the mouse buttons to the effects at the interface can still remain fairly arbitrary. Therefore the issue is how to design the interface so that the mapping remains obvious and easily understood without losing the functionality.

A partial solution is to use a single mouse button and maintain most of the functionality by mapping the semantics of the object onto the behaviour and appearance of the icon in a fairly natural way. By allowing the cursor to act more like a real life hand, such as a cursor which resembles a hand with a 'finger', the user can infer from this about what options are open. This is because the behaviour of the cursor has been mapped to directly resemble physical actions in the world.

It can be seen that research issues centre on the misconceptions that people have acquired in the past, how they influence current computer use and what can be done to overcome or exploit this. In designing interfaces for learning it is very important to minimise the learning of the interface itself. For a user to feel in direct contact, factors such as prior experience, will contribute to this factor. An experienced UNIX user may view the command language interface as more direct than a graphical interface due to familiarity with the operating system. Types of directness will also influence the degree of transparency attained. What is apparent is that there needs to be careful consideration of fairly 'low level' details in a graphical interface as these make a difference to the experience of 'directness' (Hutchins, Hollan and Norman, 1986).
Sussex, Cumming and Cropp (1994) discuss the need for a balance between power and transparency in interface design. Especially when designing the features of an interface to a discovery learning environment. When creating tools for this type of learning environment decisions need to be made over what is exactly required because the factors of power and transparency do not always run in parallel. There needs to be a decision made over the requirements for transparency, simplicity and flexibility in comparison to the needs of the learning task itself.

3.8 Graphical Environments as Discovery Systems

A central question remains unanswered: can a graphical environment necessarily enhance learning? The system used for this experiment is a hypertext environment. But work on guided discovery was initially carried out in a simulation environment. Therefore there are principles that have been derived from this type of CAI that can be applicable to constructing a hypertext environment.

In a graphical environment the issue of mapping icons to the domain they are intended to represent, remain a determinant in how easy it is to carry out discovery. Gaver (1986) investigates different types of mapping and Rogers (1989) distinguishes between concrete and abstract icons which require distinct considerations.

The issue of icon-referent mapping is made even more complex when sets of icons are meant to be related. By structuring the relations between graphic elements to reflect the relations among the referent set, these can provide visual clues about the way a particular domain is structured. Having such knowledge may be important in facilitating learning about the domain. If these relations can be communicated at the interface then this will provide the user with a collective model in which to infer the structure of the system. Using icons in this way will provide important information to the learner about the domain and the concepts within it (Rogers, 1988). Another advantage is that it can encourage the user to explore the visual relation and organisation of the objects within a system. By allowing the user to view such an organisation, this may have a facilitative effect on retention (Gittens, 1986).
Clearly icon-referent mapping is an important issue in educational applications. The manner the icons are designed conveys information about the domain to be learnt. The user can use this to base inferences on how the system operates and the features it provides for exploring a particular learning environment. As outlined by de Jong (1992), the learner interface should provide 'physical' handles on the model so that the learner can manipulate the different components of the simulation. The interface should be able to support the choice of variables and parameters as well as the changing of the values themselves.

In the REFRACT system by Reimann (1992), there is evidence that the user favours interaction using graphical components rather than a command-driven interface. When students set up experiments they were given the option of doing so in a graphical or numerical manner but preferred the former. This was especially prevalent when setting up hypotheses. The learner recognised that this method was less precise than entering it numerically; but in doing so provided an introduction to the ideas at a very general level, so that they were not being asked to do more than they could accomplish.

This also proved to be a useful indicator of how in-depth the learner’s knowledge was. The quality of the student’s hypothesis was determined by how precise the answer was (submitted in graphical form). Feedback was also given in a graphical form. The correct answers were drawn in the same window as the one where the original prediction took place. This again emphasised the benefit of providing a graphical explanation for the solution to allow the learner to compare answers. This was supported by verbal feedback via the teacher to help disambiguate any difficulties with the graphical feedback. The frequent use of graphical (pictorial) information was seen as a step to building generalisations and to generate predictions. Therefore an interface to a discovery learning environment could contain a graphical option. This principle is more applicable in an environment whereby the user has to provide a hypothesis to test without the need for an exact answer being given to the system.

Reimann described another way of enhancing the display of the hypotheses and subsequent results. The relationship between the hypothesis and the evidence should
be presented in a graphical form, so that the learner can integrate both in order to understand the underlying principles. The relation between theory and evidence is essential for understanding why one factor leads to the other. Therefore any tool which displays the reification of the link between theory and evidence will create a more instructionally effective environment. It can help the student to visualise the difference between the current learning state and the goal state. Allowing an understanding of the link between theory-evidence will guide the attention and therefore the discovery path taken by the user. It will help to reduce the cognitive demands of the theory-to-evidence comparison because the graphical representation can act as an external memory. This is similar to the reification strategies used in problem solving situations such as the Geometry Tutor (Anderson, Boyle and Yost, 1985).

There are also issues involved in navigating the learning environment, and being able to represent this at the interface level. The aim is to find the optimal or negotiable route through the information resources available. A possible solution is the use of types of graphical representations which could support navigation and learning (Fischer, 1992). These usually involve some type of map. This could be multidimensional displaying both the current knowledge base and the location of the user in the learning space. This is discussed further in chapter 5 on the design of graphical overviews.

However Sussex et al (1994) had concluded that it could be too costly in computational terms to implement graphical representations in relation to gains in learning. It was not used in their Mayday system for this reason, as Mayday was essentially a developmental and experimental tool. Their solution to the problem of cognitive overload and navigation was to limit the depth and proliferation of the learning tools, as well as ensuring that most of the information needed was always left accessible. Therefore to overcome some of the navigational problems and to structure the learning process, the design and the form of tools presented in the interface can determine the learner’s approach to the knowledge domain.

The aim of interface design was also to provide a familiar scenario or tool in which to relate the domain knowledge; to provide a familiar interface which requires less effort
to learn and that can be used to operate in the domain. This is apparent in the basic structure of CLEM (Boyle et al., 1994) a discovery learning environment for learning Modula 2. The interface resembles an electronic textbook and provides a familiar contextual framework in which to display the domain knowledge. The metaphor acts as a transitional object which allows the student to quickly make sense of the basic functionality of the system while supporting the learner in making the transition into using its more powerful features. This contextual familiarity can be seen in the incorporation of a contents page, the division of the material into chapters as well as an index section.

It was found that the users had very little difficulty grasping the functionality of the book metaphor. The issue of interface design centres on what metaphor best represents the flexibility and functionality of the discovery learning environment. But interface design for guided discovery goes further than just selecting familiar metaphors to incorporate into the system. The next section will examine the research issue of whether there are specific tools able to support learning using exploration.

3.9 Support Tools for Learning

The aim of providing support tools for learning is to allow students to gather and analyse certain aspects of the domain knowledge. The issue centres on the types of tools needed to enhance the learner’s understanding of the subject domain and what implications this has for educational and cognitive aspects of learning. In allowing the student to manipulate the results and organise it into different forms, the system is allowing the user to select other ways to approach the data which may be more suited to individual preferences.

In Reimann’s (1992) REFRACT program the learner is able to carry out experiments and to view the results as graphical information. But several tools are also provided which allow the student to analyse the feedback in a more constructive way. A recording tool in the form of a notebook was provided to allow the student to keep track of the sequence of experiments conducted. This learning tool also provided
options for re-organising the information into different forms. A data analysis tool also allowed the student to filter the data into a tabular form and apply it to statistical analysis. It is suggested that the simulation is not in itself enough to guarantee the learners understanding of the subject domain. What are needed are tools which can allow the student to 'personalise' the data so that it can be organised in a meaningful way. There needs to be support for learning when merely exploring the simulation is not enough. Therefore these tools are seen as an integral part of the learning environment.

The use of tools to enhance learning is an additional feature of the Mayday environment (Sussex, Cumming and Cropp, 1994). The tools focused the learner's attention on specific areas of the knowledge domain such as a dictionary tool, used to input search terms to obtain specific explanations of any words not understood. A help button was also provided, which offered specific types of help when the user requested it. Other tools tested how in-depth the learners' knowledge was.

Of interest was the use of several 'games' to encourage the learner to manipulate the knowledge (target words) in different ways. This was used to provides scenarios or contexts in which the words would be tested and resembled the type of exercises the classroom teacher would use to aid understanding. By having to decide which learning game to use and then working through the exercises, the learner is taking a more active role in guiding his own learning.

What is apparent is that a discovery learning environment needs to be supported by tools which can provide a greater understanding of the knowledge according to the method preferred by the user. The support tool can act as a type of tutoring component by directing the learner to the exact information required and can provide the researcher with a method for tracking the progress of the learner.

As mentioned earlier in this chapter other tools like audio facility to present the target words in auditory form and tools such as 'Meaning', 'Sentence' and 'Similar' all focus the students attention on a particular skill; in this case learning the skills of word spelling and word decomposition. The suggestion is that learning tools are provided
in order to allow users to build themselves a deeper and more informed understanding of the subject domain.

This has been discussed by de Jong (1992) with the premise that because these tools focus the learner's activities, the learning will in turn be more meaningful. The learner could use a scratchpad or spreadsheet to express a hypothesis or prediction. By offering empty scratch pads, such as a space on the screen in order to make notes, a reduction in the learners' working memory load could be achieved (Towne et al., 1990). This could be taken further to include structured or predefined scratchpads with the added benefit of guiding the learner towards the formation of a specific hypothesis or plan of discovery whilst making notes.

By giving the user tools to manipulate the presentation and depth of the data, the learner is given assistance in hypothesis formulation which is an essential part of guided discovery (Reimann, 1992). Other types of data presentation could be in the form of spreadsheets which allow predictions to be made through filling in certain areas with anticipated results as in CIRCSIM_TUTOR (Kim et al., 1989). A set of nested menus could also be used, containing certain fields which could be selected to compose a hypothesis to be later verified by an experiment (as in the Pathophysiology Tutor, Michael et al., 1989). These menus could take another form such as a set of menus which have connectors (for example 'when') to link variables (like 'price') to descriptors (such as 'decreases') to form a testable hypothesis as in the Smithtown exploratory simulation (Shute and Glaser, 1990).

The aim of providing learning tools is to aid the learner in the discovery process. Not only to find out what is relevant in a very wide knowledge space but also of using what is found in a constructive and meaningful way. The research issue could focus on the form the tools could take and how modifiable they should be to the user. This is a particularly important issue in discovery learning as critics of the approach could argue that the learner does not necessarily know what to do with a specific piece of knowledge after it has been discovered. These tools give the learner some guidance in determining how best to use and understand this new knowledge.
An examination of what the user has input into these scratchpads could be used to analyse the type of cognitive map the user forms during exploration of the learning environment. It could also help to analyse what happens when the user discovers new knowledge which may be in conflict with any misconceptions that existed previously. They can also be structured so that these scratchpads, tests and other learning tools help to focus the discovery process. Therefore new tools could be invented which help the user to visualise the search process. The concept map device used in the Guided discovery condition and the map only condition is regarded as a cognitive tool that is able to support the learning process; to encourage the learner to be engaged with the domain material and to reduce cognitive overload.

3.10 The Tutorial Aspect of Discovery Learning Systems

The tutorial aspect of discovery learning environments concerns the teaching component incorporated into the system. It examines the degree to which the system should tutor the learner when exploring the domain and is linked to aspects of guidance. If there is a change in the part the computer plays in the learning process, then there are subsequent changes in the teacher-student role. This section will examine the role of the teacher in shaping these systems and the change in the teaching process. The emphasis has shifted from teacher-led to learner-led tuition, with the user taking responsibility for discovery in the electronic space. This is linked to issues of control as well as questions concerning how visible the tutoring system should be, and how adaptable it can be to individual needs.

If a discovery learning environment is to become a viable alternative to classroom teaching there needs to be provision for other factors such as motivation, possibly in the creation of a sufficiently challenging environment. This is a key factor because keeping learners interested will ensure that they will learn using the system for an adequate length of time.

Sussex, Cumming and Cropp (1994) emphasise that the teacher should play a major part in shaping the design of the discovery learning system. There should be
extensive use of the teachers past pedagogical expertise. In the design of the Mayday system, teachers who were experienced in teaching English contributed to the choice and design of the learning tools.

This meant that to a certain extent the learner could determine his or her own learning strategies. This was referred to as metacontrol by de Jong (1992) whereby the degree of control the user had over the pace of the simulation, and the ability to set constraints on the simulation influenced how the discovery process took place. It was often found that constraints in a simulation were set beforehand by an external agent (usually the teacher) who had already pre-determined what was of relevance and the way it was permitted to be discovered.

The degree of tutoring required maybe less if the role of the system is to be part of a wider teaching process. The aim of the Mayday system (Sussex, Cumming and Cropp, 1994) was not to replace the teacher. Instead Mayday was seen as an accompaniment to teaching effective exploratory learning in the domain of language; with the teacher exploiting the facilities which the system offered. The teacher would analyse the way that Mayday was used by the learner and modify the advice given in the classroom accordingly. Therefore the discovery system and the teacher would both contribute to helping the user understand the knowledge domain.

With CLEM (Boyle et al., 1994) the use of the CORE approach was in contrast to the formal didactic, procedural method commonly used in the teaching of computer languages. The CAI system played a dominant role in teaching throughout the whole module. This signalled a change in the role of the teacher. The teacher had moved away from being a lecturer or 'imparter' of information to being a resource for the students. But CAI had not removed the need for human tutors but had changed the expectations of them. For the academically weaker students they felt less comfortable with a course mainly using a CAI type of teaching method. Therefore not all learners will wish to solely base their learning on this type of instruction. A discovery learning environment may not be a total solution for all academic levels of education, but can offer varying levels of benefit to most learners. In terms of distance learning the learning system may be the only resource for the main bulk of the teaching (this is discussed further in chapter 6).
It can be gathered that the level of tutoring required still needs to be fully researched. The degree of tutoring to be incorporated is problematic because the paradigm of discovery learning is one of student-led exploration whereas there is a requirement for system interventionist strategies. The student cannot be expected to be given a tutoring system which can replicate the sort of lesson that would be received in the classroom. But there must also be enough tutoring for the learner to understand the underlying concepts which reside in the knowledge presented.

As Thornton (1990) argues some concepts cannot be taught using lectures, so a simulation containing a tutoring component and supported by teacher intervention could provide a possible solution. But CAI will never completely replace the competent teacher and ITSs are presently unable to offer that degree of competency. Recent developments in educational technology indicate a shift towards the increasing use of simulations in educational practice.

What is needed is a 'shared world' or 'collaborative manipulative' style of interaction (O'Malley, 1990) which needs to be extended to include not only the learner and the tutoring system, but also the human tutor as well. In the case of learning via the Internet, there needs to be support which may still rely ultimately on contact with a human tutor.

### 3.11 Learning Outcomes in Discovery Learning

The learning outcomes which can be promoted by this style are problem solving, both for defined and concrete concept problems. Learning in guided discovery style induces a learner to develop more cognitive skills than other styles used for teaching (Mosston and Ashworth, 1990). This is discussed further in chapter 4, which considers guided discovery in relation to other possible learning styles which could have been selected for the guided discovery system.
In terms of cognitive development, this problem-solving ability may be transferable out of the classroom setting. Therefore the objectives of guided discovery are to engage the learner in a discovery process with the final result being the recognition and understanding of the single correct answer. To develop an explicit relationship between a learner's discovered response and the teacher's stimulus that elicited that response. This will aid the learner in developing discovery skills that will lead to skills useable in other situations; applying logical, sequential discovery skills to new subject areas. This is seen as the acquirement of metacognitive skills. But learning outcome is affected by motivation, as motivation can determine if the learner will become cognitively engaged in the material to a high enough degree to want to explore it. There are also specific skills that the learner will acquire after using the discovery learning approach.

3.11.1 Motivational Outcome

The issue of motivation centres around how the learner can be encouraged to learn material which may be regarded as mundane or too technical, leading to reluctance and avoidance behaviours. Generally, learners felt motivated to explore a discovery learning environment.

This was found by Dong and Wang's (1990) study which found that students wanted to repeat usage in the future. Even those who scored lowly in the post-test wanted to use it again. In the Mayday environment (Sussex, Cumming and Crop, 1994), again users of the system for language learning found that they were more motivated to learn concepts and areas which they had previously found difficult to do. This was found to be true for the Smithtown environment (Katz and Ochs, 1993) whereby learners would use on average at least two and a half hours; discovering more principles and asking more questions than they would in a lecture. Therefore system use was markedly higher than expected. Activity during exploration was seen as a component for being able to prevent boredom and to increase motivation (Sebrechts and Marsh, 1989).

The ideology of the paradigm itself can be viewed as interesting and motivating to the learner. Learning by discovery, such as using experimentation, allows students to
uncover new facts and relations using their own intuition as well as guidance by the system. As Lee (1994) comments:

"realising a truth via a discovery is exciting" (pp.304).

Hypothesis-driven learning, a facet of discovery learning, requires a high level of learner participation and this helps to make it intrinsically motivating. It raises self-esteem when the student discovers that the hypothesis has been proven correct (Reimann, 1992). Discovery learning can encourage the student’s innate curiosity, so that the next time the learner encounters an unfamiliar domain, the metacognitive skill to explore it is already there (Ostrovsky et al., 1991). Eventually the learner will be able to ask questions and construct methods to guide the discovery learning process for tackling new domains without prompting by the system.

These results showed that students with varying abilities would benefit from using discovery, and were replicated by the work on the Smithtown discovery environment (Katz and Ochs, 1993). Looking at the post-test it was implied that the typical use of Smithtown enabled weaker students to improve their final grades by approximately quarter of a letter grade. Students who did not use guesswork as a discovery strategy (selecting or suggesting answers randomly) were able to raise their grades higher. After controlling for differences with student aptitudes, the difference turns out to be an average margin between passing and failing the module.

The learner is able to just 'plough' through the subject modules using trial and error until they reach the end of the program and input the required solution without really understand the answer. Jacobs (1992) regarded this as a natural way that people will work through an overtly structured learning machine. Therefore the issue is how to make the learning task interesting as well as also ensuring that they are guided to all the relevant material.

To attempt to make the learning environment challenging there is the inclusion of games (Sussex, Cumming and Cropp, 1994) which require learner input. In some cases the user is given a target to aim for by scoring points. Lee (1994) argues that in using a scoring system there is a two-fold advantage: it helps to keep learners
interested in exploring the domain, and also to teach them other benefits related to the subject domain. Such as selecting hypothetical tests which in the real world would affect hospital budgets if they were carried out unnecessarily.

Several advertising and teaching manuals attached to educational software claim to offer the benefit of being fun and enjoyable. But there is no evidence to claim that the user will learn about the strategies of problem solving just because the software has 'fun' elements (Markle and Tieman, 1991).

Research suggests that generally pupils do learn using both discovery and guided discovery learning. But not only do they learn the subject domain but also learn transferable skills that can be used in new domains and learning situations. Discoveries when using the system do feed back to improve final grades. This is also strengthened by the findings that pupils are more motivated to learn the subject in a guided discovery environment, which may be regardless of the actual grade that the pupil achieves. However other findings have not made this benefit of using discovery learning or guided discovery so apparent. The next section examines the skill set that the guided discovery approach can promote.

3.11.2 Skills Acquisition

Learning outcomes have been measured in several ways and there have been many claims about some of the skills that are taught, aside from learning directly about the subject domain itself. The discussion in this section will examine other skills which the learner has learnt whilst using the discovery learning and guided discovery approaches.

In terms of what is considered to be genuine ‘discovery’, it is suggested that discovery is not just about finding facts, recalling correct spelling or locating positions on a map. These can be carried out whether or not the teacher is there to tell the pupil; or even if there was no intention to learn these things. Instead genuine discovery is identified as deeper processing and the reconstruction of knowledge. The learning outcomes are that the learner will achieve higher levels of learning; in the form of structures such as the operation of rule-based systems, learning strategies such as how
systematic problem solving works, and classification schemes imposed by the teacher or the learners themselves (Markle, 1992).

From research on cognition and motivation, and Reimann's (1992) own studies, a hypothesis-guided approach to learning has effects on three levels: (a) in terms of cognitive effects the acquired knowledge is well structured and flexible to apply, (b) the metacognitive effects are that the student becomes aware of strategies to search for information actively and (c) guided learning is intrinsically motivating and raises self-esteem. The learner does not just produce experiments but also creates predictions and hypotheses based on the experimental data. It could be said that learners are able to use what they have learnt, know different ways to approach the problem and gained greater self-confidence when approaching new domains. It could be argued that this method of asking questions are similar to the guidance in the discovery steps used in this project to focus the users' attention (see chapter 8 for the discovery steps). Ostrovsky et al (1991) designed their subject material with questions already pre-set in a guided manner; starting with questions such as “Why is this substance the way it is?” and “How does nature make this substance work the way that it does?”

In Dong and Wang’s (1990) study on guided discovery in teaching students proving skills in geometry, they also found several positive outcomes in learning. In terms of understanding the subject material the learners made more progress in their mathematical achievement than those who did not use the guided discovery system; showing improvements both in the training of proving skills, and an overall increase in the students’ mathematical achievements. In terms of attitudes towards the system most students had a very positive attitude towards this type of software and wanted another lesson using it, hence showing a favourable approach towards this type of tutoring style and learning environment.

In terms of metacognitive skills, this type of tutoring supported learners in understanding concepts, and improved their ability to carry out judgement decisions. By being taught discovery skills from using the system, the deductive skills of the learners were enhanced as well as how to how to go about tackling previously unencountered problems in a logical manner. The findings by Katz and Ochs provide
evidence that the discovery world approach may be a promising tool for strengthening students' problem-solving skills. The results in their study are consistent with support for the effectiveness of discovery learning. Because their system was used with instructors and as part of a module, it could also be concluded that the approach is both pragmatic and applicable to large-lecture oriented classes.

Also another advantage is that the teacher using or building the environment and the learner using the environment can both benefit (Mayes, 1993). The Mayday environment (Sussex, Cumming and Crop, 1994) found that teachers helping to build the system made them re-think the nature of the learning process. This was confirmed by Ostrovsky et al. (1991) that the process itself, of designing and implementing the system, had important benefits for the participants.

3.12 Discussion

There are many processes involved in Discovery learning. The paradigm of exploration, discovery and guidance had appeared in education in the past but it had never really gained widespread acceptance. But this educational pedagogy seems particularly suited to current technology, providing a framework for the design of hypertext and the Internet as educational environments. Many issues of discovery based learning remain unresolved.

In the diagram in chapter 2 (Fig 3) which outlines Guided Discovery Learning and its possible research areas, this provides a guide to the research issues for consideration in this thesis. What is suggested is that this educational pedagogy should ideally be reflected in all levels of system design, from psychological theories concerning learning to the design of the interface itself.

In issues relating to guidance there are questions over the amount of control the user should be given. The ideas underlying discovery learning emphasise the need for learner-led exploration; but evidence has shown that there is a need for guided
tutoring. The value of instructional cues in providing the learner the structure that is needed during the discovery process needs to be examined further.

Related to this are the reasons behind linking. Why do designers of these environments create certain links to direct the learner towards specific areas of domain knowledge? What do they expect these links to achieve and how can these links be displayed to aid memorisation and navigation? These issues will be discussed further in chapter 5 (Research Issues in Hypertext for Learning). What is apparent is that hypertext remains an educationally attractive tool for carrying out guided discovery learning. Hypertext in itself is not a very interactive environment but when coupled with structure and feedback, it may increase the experience of interactivity.

In terms of design the system needs to be structured so that it can tackle different aims and cope with individual differences in users preferred learning styles. Some discovery learning systems were structured to encourage collaborative work, replicate real-life situations and act as the mainstay in tutoring complete topics. The CORE guidelines provided a methodology for designing a guided discovery system; taking into account issues of context, the introduction of new material and user testing. The learner should also be given tools to explore the educational environment.

There has been research over how the user can operate in this virtual world. The design of metaphors and 'bridging analogies' are used to provide cognitive 'anchors' in an unfamiliar context. Planning determines how the learner is to approach the material to be learnt and it remains an essential part of the discovery learning process. The interface should support the learner in carrying out this planning by providing tools that aid this process.

There are many areas of interface design which need to be investigated. The syntax of the interaction has to be as understandable as possible for the learner. The use of a familiar scenario, such as an electronic textbook, will help to orientate the user and communicate what options are available at that particular point in the learning process. Graphical environments can make the link between theory and evidence more understandable, leading to a realisation of the underlying concept.
Linked to guidance is the tutorial aspect of the discovery-based system. The role of the teacher has changed and with this has been a shift towards learner-led education. There needs to be an examination of the type of tutoring structures which are suited to these changes. The tutoring component has to be able to motivate the learner to explore, test the knowledge to ensure that it has been acquired and allow the user to follow self-directed exploratory paths unless detected to be wrong.

3.13 Conclusion

The literature reviewed so far characterises discovery learning as a subject that lacks a core of established guidelines for carrying out the design of environments able to promote this as a paradigm for supporting learning. Some strands can be drawn, such as the need for the learner to take an active approach in working through the material and to self-determine the path through the domain material.

The chapter carried out an initial discussion of the origins of the discovery learning approach, the different forms that discovery systems have taken; and specific design issues such as interface design, domain representation and tutoring intervention. Although there have been evidence of the effectiveness of this approach, much of the research has not been systematic and there remains a lack of quantitative data about its success or established guidelines for designing such systems.

What is apparent is that learning through discovery is a complex process which involves more than just allowing the learner to search through the relevant material. This project proposes a guided approach to discovery learning, using a structured framework for the design of the whole learning episode as well as in the design of the system itself. A methodology for carrying out this educational paradigm is given in chapter 4 and its application as a WWW hypertext environment is given in chapter 8. Using the Internet for education remains an unprincipled approach with a collection of disparate forms of materials and assumptions about the way students learn. It is suggested that using a structured tiered approach to the design of hypertext systems, able to provide guidance, will lead to more effective learning.
Chapter Four

Guided Discovery and Teaching Styles

4.1 Introduction

This chapter will examine the Guided Discovery approach in relation to other teaching styles. Guided discovery is the focal point of this research topic and is the main pedagogical premise which shapes how the system functions in its relationship towards the learner and the hypertext learning environment. It is related to chapter 8 on the architecture for a guided discovery hypertext learning environment because it forms the main instructional strategy for the operation of the guidance component and the operation of the system overall. A contrast will be made with other similar teaching styles to highlight the differences of this approach examining the different components that comprise the teaching style.

Guided discovery has been criticised as an ambiguous approach to teaching (see chapter 2), hence this section will attempt to establish a framework for operationalising this approach. This chapter will begin with a discussion of how to categorise teaching styles, establishing a framework in which different pedagogical approaches can be inserted. The guided discovery style will be placed within this framework, with an anatomy of the teaching style. This approach will then be contrasted with the convergent discovery approach, which provides little structured guidance.
4.2 A Framework for Understanding Teaching Styles

There are many pedagogical approaches to teaching. To understand the similarities and differences between the approaches it is suggested that they should be placed along a spectrum of learning styles. This spectrum of teaching style (now referred to as spectrum) was put forward by Mosston and Ashworth (1990, 1994) and is an approach for understanding teaching in the classroom. This is an integrated structure for teaching which provides a contextual framework for the various styles used in teaching. Another description is to view the spectrum as a map displaying the different teaching styles and the relationships among the teaching elements within each style. This spectrum can be used to display the macro-conceptualisation of the teaching act as a whole, or move down to a lower level to provide a micro-level view of particular instances which are part of the teaching style. The discussion will now centre on a definition of teaching.

4.3 Definition of Teaching

Teaching is discussed by Mosston and Ashworth (1990) in terms of a human teacher in a classroom setting. The translation to computer-pupil instruction will be discussed in chapter 8. It is useful at this point to discuss the different teaching styles that are used in a classroom scenario to aid understanding of how it can be transferred to a computerised learning environment.

Teaching is defined as:

"a special human connection ... subjected to a tacit agreement to share information, to deliver and receive accumulated knowledge, to replicate portions of the past, to acquire and discover new information and to construct and create pathways for the yet unknown" Mosston and Ashworth (1994).

Teachers are faced with making decisions concerning educational goals, lesson objectives, motivation, material design and assessment. The decisions they make
concerning such issues will be reflected in the teacher’s behaviour. These decision patterns are referred to as teaching styles, with the framework containing them as the spectrum of teaching styles. This is useful as a model for identifying the structure of each style by differentiating the decisions between the teacher and learner. A main theme that runs through this spectrum is the shift in decision-making from the sole responsibility of the teacher to the main responsibility of the learner, as teaching styles shift across the spectrum. As Mosston and Ashworth go on further to say:

“It is the ability to behave in a deliberate manner, using a style that is most appropriate for reaching the objectives of a given episode” (1994).

Therefore how teaching style should be assessed is discussed next. This will help in understanding the characteristics of guided discovery and also provide a methodology for designing a guided discovery hypertext environment for the WWW.

4.4 An Overview of the Spectrum of Teaching Styles

A fundamental proposition is that teaching is governed by a single unifying process, that of decision-making. The teacher determines, before the educational episode, which type of behaviour (teaching style) will be carried out. These primary decisions and their subsequent effect on other parts of the learning process are illustrated in the structure of teaching styles as six underlying premises which are described below:

- The axion – this is based on the assumption that every act of teaching is deliberate, and is a result of a previously made decision.
- Anatomy of the style – these are the decisions carried out for a teaching-learning episode and is comprised of the pre-impact, impact and post-impact set (described in section 4.6).
- Decision-makers – This is the teacher-learner relationship, whereby if the teacher makes the decision, there is a subsequent reduction in the learner’s ability to do so.
Spectrum – by establishing the factors of who makes the decisions, what they are and when they are taken, Mosston and Ashworth have identified the particular structures of 11 different learning styles.

Clusters – different clusters (or groups) of teaching styles produce different cognitive abilities such as reproduction (replication of known knowledge) or production (creation of new knowledge). These are given alphabetical labels as points of reference. A-E teaching styles foster reproduction of knowledge and engage the learner in primarily cognitive operations (such as memory, recall, sorting, identification) and deals with factual data, rules and procedures. Styles F-K evoke production of new knowledge, whereby learners discover single correct concepts.

Developmental effects – each teaching style influences the learner in a particular manner. The effects of each style can be divided into cognitive, social, affective, physical and moral domains.

Mosston and Ashworth denote the different teaching styles as alphabetical labels, ranging from A-K. A-E teaching styles are: (A) Command Style, (B) Practice Style, (C) Reciprocal Style, (D) Self-Check style, (E) Inclusion style. F-K are: (F) Guided Discovery style, (G) Convergent Discovery style, (H) Divergent Reproduction style, (I) Learner-Designed Individual Program Style, (J) Learner-Initiated style, (K) Self-Teaching Style. The differences between A-E styles and F-K styles are in the shift from reproduction of knowledge to production of new knowledge, and this is signalled by a movement through the discovery threshold which lies between E (Inclusion style) and F (Guided Discovery) styles of learning.

The concentration in this thesis is on teaching style F. A comparison could also be drawn with Ferguson’s (1992) CAI activities in relation to learner control (Figure 1, chapter 2). Style A could represent a traditional Drill-and-Practice program whereby the learner has no decision over the instruction; and Style K could be a free exploratory environment with the learner exploring an open-corpus (Ibrahim and Franklin, 1995) WWW environment with no guidance. Style F (Guided Discovery) is an exploratory
environment with sequencing of steps and embedded questions designed to evoke smaller discoveries; which is the research area of this project.

4.4.1 Representing the Pedagogical Unit

The interaction between teacher and learner will create a particular type of teaching behaviour, learning behaviour and specific set of objectives. Each style is defined by the particular behaviour of the teacher (the decisions previously made by the teacher – T), the particular behaviour of the learner (the decisions previously made by the learner – L), and the objectives that this relationship attains (O). The objectives can be subdivided into (a) subject matter objectives which relate to an understanding of a particular learning episode (e.g. recalling facts, using rules) and (b) behaviour objectives related to certain human behaviour (e.g. performance accuracy, self-assessment, replication). The T-L-O relationship can be viewed as forming a pedagogical unit with each teaching style having its own distinctive T-L-O unit. These are illustrated in figure 5.

Figure 5: The T-L-O Relationship with the addition of Objectives (modified from Mosston and Ashworth, 1990)

The suggestion of this structure is that there is an inseparable bond that exists between the different components, and that these constitute the educational approach of a
particular teaching style. Therefore the objectives of an episode are to decide specific teaching behaviour, which will in turn influence learning behaviour resulting in specific outcomes in terms of subject matter and behaviour. 'Thinking' is an ambiguous term but is used here to describe an essential part of the teaching-learning experience. Hence a discussion will follow of the assumptions and theories concerning thinking and the effect of teaching on thinking, and how it is operationalised to differentiate teaching styles.

4.4.2 Processes and Operations Involved in Thinking

There is a vast amount of literature on thinking, cognitive processes and learning (Cohen, 1989). Mosston and Ashworth provide a discussion of various thinking processes and cognitive operations that characterise teaching-learning styles.

Conscious thought is proposed as being comprised of three basic thinking processes: memory, discovery and creativity. Memory processes provide the reproduction of knowledge (e.g. facts, dates, names, procedures, rules). The discovery process allows the learner to find out about knowledge previously unknown (e.g. understanding concepts, relationships between entities, principles and theorems). It is distinct because it involves the production of new knowledge. The creative process is the production of completely new knowledge unknown by anyone (e.g. new formulae and new products). The creativity component is not examined in this thesis but remains an area of interest in terms of how it affects learning processes.

4.4.3 Mediating Thinking

The manner in which each of the above categories of thinking are arrived at can be described as a S-D-M-R sequence.

- **S** - Stimulus
- **D** - Cognitive Dissonance
- **M** - Mediation (searching)
The stimulus (S) will create a need to know within the learner, a state of cognitive dissonance (D) leading to a search for an answer (M) through the memory, discovery and creative process. A response (R) will be given in terms of a solution, new product or idea. This can be viewed as figure 6.

Stimulus (the trigger)  ----> Cognitive Dissonance (the need to know)  ----> Mediation (the search)  ----> Response (the solution)

Figure 6: Flow of Conscious thinking (from Mosston and Ashworth, 1990)

Certain questions will trigger a particular type of search, which may use memory, discovery or creativity. The stimulus may also create an overlap between these different episodes of thought. So some stimulus may lead to the primary use of creativity but only after recall of specific facts, hence using creativity as a primary process and memory as a secondary process. Therefore the categories of questions used in each of the S-D-M-R phases are a crucial factor in structuring thought.

In terms of structuring discovery through questioning, with cognitive dissonance there is a need to search for a solution. There must be a perceived need to know which will motivate the learner to search for a solution. The learner will engage in specific cognitive operations which have been triggered by the specificity of the stimulus in terms of mediation. A question may be formulated to ask the learner to compare information. Other questions can be used to elicit other operations such as contrasting, categorising, hypothesising; but only if there is a need to do so by the stimulus. Many cognitive operations can be used to find one solution; these can therefore be divided into two functions: a dominant function and a supportive function. For example if the dissonance required the use of categorisation this will be the dominant function but a secondary function could be memory in order to recall specific facts to aid categorisation. After the mediation process, there will be a response which will signal an end to the cognitive
dissonance and will be a consequence of mental processing using memory, discovery or creativity.

The three basic thinking processes of memory, discovery and creativity can lead to two types of thought, convergent thought and divergent thought. When for example using discovery, the learner can follow a convergent path (which means the discovery of a single path or single concept), but it is also possible to take a divergent path (whereby there are multiple solutions to the same problem). This is also the case with memory or creativity. In summary the stimulus triggers cognitive dissonance, which will determine the path to be taken during mediation (a convergent or divergent path). After the mediation phase, the result will be in the form of a single or multiple response derived from memory, discovery or creativity.

4.4.4 The Discovery Threshold

Between the teaching styles that make use of memory and those teaching styles that use discovery there is a demarcation in the form of a discovery threshold. The teaching styles from A-E rely primarily on a memory cluster of teaching styles. The role of the teacher is to “deliver” knowledge for the learner to “receive”, with no real active engagement except memory. The learner has to remember how to compare, contrast and solve, by replicating the teacher’s actions. When the learning episode shifts to discovery, the learner has to cross this discovery threshold. The teaching behaviour changes to one of questioning and active engagement by the learner during discovering. A more simplistic description is to view the spectrum of teaching styles that range from a cluster of A-E of using the cognitive ability of reproduction, and the clusters of styles from F-K of utilising the cognitive ability of production of new knowledge.
4.5 Determining the Anatomy of a Particular Teaching Style

The composition of any teaching style can be divided into specific sections of decisions in the teacher-learner relationship (Mosston and Ashworth, 1990). These decisions are organised into three sections - the preimpact set, the impact set and the postimpact set - which a teacher or courseware designer should consider when designing a teaching episode. These can be used in the design of the guided discovery system in this project to determine the design decisions that need to be made, so they will be examined in further detail.

The preimpact set consists of all the decisions which are taken before the teaching episode; these define the intent of the style. This includes the selection of the teaching style (T), the learning behaviour itself (L) and the objective of the learning episode (O), in the T-L-O relationship described in section 4.4.1. Learning style is the particular preference of the learner for a particular stimulus or task (see chapter 8 for learning styles), and the teacher can select a style of teaching to suit learner preference. Decisions need to be made about whom to teach (either as a class or as individual students), the subject matter (in terms of type and quantity of material) and quality of learner performance in the given task. The teacher must also decide when to teach in terms of pace, duration and total length of time taken for the whole learning episode. There also needs to be the creation of evaluation procedures and materials to determine performance by the students.

The second part of the teaching style is the impact set. This is the implementation of the decisions taken in the preimpact set. To adjust any decisions and to rectify any problems with the teaching style, students learning style, subject matter and related teaching issues.

The postimpact set is the final part of the teaching style. It deals primarily with decisions concerning the evaluation of the tasks previously carried out. This includes an assessment of whether the aims of the preimpact set have been achieved in the impact set. Information about performance has to be gathered, this has to be compared against
specific performance criteria and feedback can be given to the learners about their performance. Feedback can be delayed or immediate and can be in the form of value, corrective, neutral or ambiguous statements to inform progress. Assessment is also made about the selected teaching style in terms of its effectiveness, and also whether the learning style of the student has supported the achievement of the objectives of the episode.

Therefore when constructing or identifying a teaching style there are three sets of decisions – the preimpact, impact, and postimpact sets – which need to be taken into account when constructing any teaching-learning relationship and which determine the operation of the teaching style. Some of these decisions can be excluded according to the perceived learning objectives of the teacher. This anatomy of learning styles can be used to breakdown different types of teaching models or strategies. It is applied here to illustrate the components and characteristics of the guided discovery approach. It is referred to in the construction and design of the guided discovery WWW hypertext system (chapter 8) whereby it is combined with guided discovery principles and used as a methodology for system design.

4.5.1 The Guided Discovery Style of Teaching

Guided discovery learning is referred to as Teaching Style F in the spectrum of teaching styles. The particular premise of this approach is to cross the “discovery threshold” and to use the production of new knowledge, as the understanding of concepts and principles. Mosston and Ashworth (1990) view discovery learning as one side of the spectrum whereby different learning styles create different sets of conditions and relationships. At one extreme of the Teaching Styles spectrum are reproduction styles of learning, such as the Command style (style A) whereby the key objectives are: composed uniformity, replication, precision, time constraints and immediate response to stimuli. This is in contrast to discovery learning whereby the learner is taken across a ‘discovery threshold’.

The guidance part of this style is partly from the teacher creating a series of questions which elicit a single correct response that is discovered by the learner. Using a guided
discovery in the converging process, the learner will discover the desired concept, principle or idea.

4.5.2 Objectives of the Guided Discovery Style

The objectives are pre-determined by the teacher in terms of the learning goal, whether it is a single concept or the understanding of a particular principle. In short, to gain the "eureka" effect (Bruner, 1966). For behaviour objectives, the learner has to be cognitively engaged in discovery in carrying out convergent thinking. To attain cognitive efficiency, there should be the provision of minimal, logical steps to lead the student to the target, without wasting cognitive resources on non-optimal searching strategies.

4.5.3 Control Issues in this Style

The teacher has control over decisions about structuring the material and the sequence the learner will follow in the preimpact phase. Main issues centre on the aim of the teaching episode and the subsequent design of the questions to guide the learner to the target concept or principle, which is a main research issue in this thesis.

The learner only gains more control in the impact phase. The student has to decide which parts of the subject matter, presented by the teacher, are of relevance for further exploration; working through a sequence of question-and-answers previously created by the teacher.

In the postimpact set control over the learning process is shared. The teacher verifies the learner’s response to each question or clue and the learner can also do so if this option is provided. This sequence of continuous decisions made by the teacher, and the waiting for a learner response, differentiates this teaching style from others in the spectrum.
4.6 The Anatomy of the Teaching style

4.6.1 The Preimpact set

The teacher has to determine the concept that has to be discovered, the sequence of steps (questions) which will lead to a chain of smaller discoveries by the learner and the size of the steps. In designing these steps, each response by the teacher should be as a reaction to the response given by the learner in the previous step. Therefore each step must be carefully designed and tested and proven as the most efficient at that particular point in the sequence. Figure 7 illustrates the structure of the discovery steps. There must also be an internal connection between steps that is related to the structure of the subject matter. In this project, a conceptual model has been used to break-down the material, and to formulate the size of the steps that are required to understand a particular concept.

To be able to design related steps, the teacher needs to be able to anticipate the possible responses that the learner will give to a particular question or clue. In guided discovery the onus is on the teacher to precisely design questions which will elicit the correct responses.

Figure 7: The Structure of the Discovery Steps (Mosston and Ashworth, 1990)
In some respects the performance of the learner is directly related to the performance of the teacher. The decisions taken by the teacher in relation to the discovery steps are:

- The objective or target to be reached.
- The direction of the sequence of steps.
- The size of each step.
- The interrelationships of each step.
- The speed of the sequence of each step.

4.6.2 The Impact set

The teacher's role is to decide the sequencing of the questions, to allow a certain period of waiting for the learner's response, to provide frequent feedback, to determine the speed of the questions and to inform the learner that the correct target has been discovered. In this case, this experiment used online testing. The main characteristics of the teacher's role are to:

- Never tell the answer.
- Always wait for the learners' response.
- Provide frequent feedback.
- Create and continue a climate of acceptance and patience.

The role of the learner is to seek a solution to the question posed, with periodic teacher feedback to guide the discovery process. The learner should continue to perceive the feedback as encouraging or explanatory even if the answer given was incorrect. Hostility will reduce the motivation to discover, as the emotional and cognitive streams are interconnected in this teaching style. In some ways this is similar to cognitive scaffolding (discussed in section 8.3.1) whereby the system provides feedback until it has been ascertained that the learner no longer needs such structured support.
4.6.3 The Postimpact set

The role of the teacher in the postimpact set is to provide the learner with frequent feedback, either to reassure the learner that the answer to each question is correct or that the exploratory process is able to lead to the discovery of the target. The feedback integrated into the postimpact set is unique to this particular teaching approach. Feedback is built into every step of the impact phase and it continues to appear in the postimpact phase. Positive feedback will encourage the learner to carry on with the discovery process and the solution acts as the reward. If, during the process of guided discovery, the response of the learner is less concrete or incomplete the teacher is able to:

- Repeat the question or clue. If the response is still incorrect, then another question should be given which provides a smaller conceptual step for the learner to grasp.

- Pose further questions asking the learner to pay attention to other aspects such as “have you checked the answer?”, “is more time required?”. This also provides the learner with the impression that the teacher is patient and is willing to check that the learner fully understands the current stage before being moved on to the next one.

The role of the learner is to examine the feedback given by the teacher (whether this is a computerised learning system) and to use self-assessment to determine progress, if this functionality is built into the task or system. With the emotional threshold in the Guided Discovery process, it is by its very nature, stimulating a different emotional state to other teaching styles. The learner is dependent on specific stimuli being produced by the teacher. Therefore the learner has minimum independence in determining what is to be learnt next or the form that the material will take. In terms of the social channel of the learner’s emotional state, there is minimal contact with other learners, concentrating instead on interaction with the teacher. There are significant changes in the cognitive developmental channel. The learner is deeply engaged in the interaction between the
teacher's presentation of the material and the eventual crossing over of the discovery threshold, thus there is maximum cognitive development with the learner being engaged in an active search for a solution. The postimpact principles are derived from Mosston and Ashworth (1990) and are extended to create a computerised environment in section 8.3.3.

4.7 Guidelines for Selecting and Designing Subject Material for Guided Discovery

4.7.1 Suitability of Tasks

Tasks that are suitable for this particular approach to teaching are:
- Categories such as concepts, principles, entity relationship, order or system, causal questions, and metacognitive strategies such as how to discover.
- The topic or target must be unknown to the learner, since the student cannot discover something that is already known.
- The topic should not be a fact, date, specific word or name as these are more amenable with the use of other teaching styles included in the spectrum.
- Do not infringe on religious, political, sexual or personal sensitivities.

4.7.2 Task Design

To determine how to design the task to support guided discovery there are four principles (Mosston and Ashworth, 1990):
1) The use of a detailed series of stimuli. These can be in the form of statements, during the setting of the scene (see figure 8), or others as questions to elicit certain cognitive processes for discovery.
2) Each question should be designed to evoke a single, correct response.
3) The questions should be administered in a very specific sequence. The sequence should move the learner towards the educational goal.
4) These steps composed of smaller discoveries should accumulate until the learner discovers (or converges upon) the target concept.

The ratio of steps is variable depending on the background of the learner and the material being taught. The first few initial steps will be used to set the scene so that the learner is introduced to the material from a known starting point. The steps which follow lead to the actual convergent discovery. These steps are the critical point. The first question will trigger the beginning of the mediation phase, and during the mediation process the learner moves from the known to the discovery of the unknown. The learner will then be taken through an S-D-M-R process, whereby every step will lead to the use of cognitive skills apart from just memory. The steps will continue until the learner reaches the desired solution. The sequence of relationships between the questions and the corresponding responses are shown in figure 8.

![Diagram](image)

**Figure 8: Guided Discovery steps with the Inclusion of Tangential Responses**
(Mosston and Ashworth, 1990)
If the student gives an incorrect answer, this will suggest that the learner has gone off at a tangent - that there has been difficulty in following the sequence of guided discovery steps. This may have been due to a badly designed question, or the step from the previous question is too conceptually large to be able to bridge. It may be useless to repeat the same question again. Instead it may be more beneficial to provide additional questions to bring the learner back into the sequence of steps. Therefore designing additional steps for providing guidance is an essential part of the construction of a guided discovery teaching episode. This is a fundamental part of the guided discovery approach, and is an extension of the guided discovery steps beyond that outlined by Mosston and Ashworth (1990). It is suggested that there should be many different levels of guidance, whereas Mosston and Ashworth do not provide guidelines for how many steps there should be, the level of understanding that they should be aimed at and how to design such steps that require less of a conceptual leap on the part of the learner. When viewed in the perspective of this thesis, the design of the discovery steps could be regarded as taking a more granular, lower level approach.

4.7.3 Designing the Sequence of Questions

The design of a sequence of steps remains a particularly problematic part of the guided discovery style. Considerations should be: (a) the objective of the learning episode, (b) setting the scene, (c) the initial question to evoke discovery learning, and (d) the size of the steps. Techniques for the design of questions are included in chapter 8, Design of the Guided Discovery Learning Environment for the WWW.

This style is different from other teaching styles that use questioning because of the particular manner in which the questions have been designed and their subsequent implementation as a sequence of steps. Other teaching styles have a different design and usage of questions to elicit cognitive engagement with the material.

Although guided discovery learning can be used in groups, it remains most effective in a
one-to-one learning situation (Mosston and Ashworth, 1990). Learners discover at a different pace and they will discover at different steps in the sequence. Therefore if one student utters the answer the other class counterparts cannot carry on the discovery process. If each individual learner works through the sequence and individually carries out the discovery at every step, the chances for remembering what is presented are claimed to increase (Bruner, 1966).

It could be argued that the learner is not given the freedom to explore the material, that they are locked into following a particular sequence of teacher-led instruction and forced to approach thinking in a restrained way. The suggestion is that a predetermined sequence of questions will not be able to cope with all the different learners. But Mosston and Ashworth view this as one of the strengths of this particular teaching style. Following a sequence of questions will encourage the learner to approach the material with a goal. The teacher has to understand the structure of the task and the material in order to design the stimulus, and this knowledge can be passed onto the learner. There will be a requirement to adjust the steps and the questions to suit different learner characteristics.

4.8 Contrasting Guided Discovery Style with the Convergent Discovery Style

The Convergent Discovery Style (style G in the spectrum of teaching styles) maintains the concept of learning by discovery but it differs in many key areas of teacher-learner control and learner roles. The main difference between the Convergent Discovery style and the Guided Discovery style is in the type of guidance clues from the teacher.

There is no guidance unless the learner requests it or if it is absolutely necessary. This is not a completely free, exploratory environment as the teacher continues to monitor the learner’s progress. Instead the expectation is that the learner will explore and ‘converge’ on the correct solution or desired rule. Therefore the level and type of guidance is
different between this and other teaching styles, with a marked reduction in teacher
guidance during the discovery process.

Returning to the S-D-M-R stages, a problem is set as the stimulus. As the learner tackles
the problem through trial and error there will be a state of cognitive dissonance, which
will shift to mediation in the search for the solution. In terms of certain role objectives,
the aim is to discover the singular correct responses to cross the discovery threshold. In
terms of the cognitive channel the requirement for the user is to go through logical
procedures; using reasoning and critical thinking as specific cognitive operations.

The discovery process utilises several cognitive operations:

- The comparison of data from carrying out experimentation of hypothesis.
- The organisation of the compared data into categories.
- Deriving conclusions from each category.
- Identifying the relevant principles, which will result in a single rule or principle.

The shift in control is towards the learner; with the learner being given decision-making
over the learning process, allowing freedom to decide:

- Stages of the discovery process itself.
- The application of relevant cognitive operations to solve the problem set.
- The discovery of a single correct solution.
- Verifying how appropriate the solution is in relation to the initial problem set.

The role of the teacher in this teaching style is divided into designing the problem and
observing the learner. To present the learner with the problem, and then wait to analyse
subsequent progress with the material. In this waiting period observing the learner is the
only action to take; with a requirement for patience, and no intervention. The basic
premise is that thinking takes time, hence the discovery process entails the learner sifting
through the information and deciding what the correct solution is for the problem. The
teacher may only participate when verifying a solution; asking questions to ascertain this. Therefore the main role of the teacher in the convergent discovery process is to present the problem or issue, to observe the learner's cognitive processes; providing feedback and clues only when requested without actually providing the answer. This is in contrast to guided discovery whereby the teacher has more control: providing continuous feedback, a higher degree of intervention concerning what to learn next and structuring the feedback and clues to lead the learner to the target answer or principle.

4.9 Conclusion

A framework for constructing guided discovery components has been proposed. It provides a method for analysing different teaching styles, highlighting the strengths and weaknesses of them. The division of teaching styles into specific stages, with clear-cut requirements, is used to determine the form that guided discovery should take in the design of the guided discovery system in this project. It is referenced in chapter 8 when discussing the design principles that have been used in the system, and has been extended to encompass particular requirements of hypertext, distance learning and Internet technologies. It has been used as a template for the design of the guided discovery learning episode used in this experiment.
Chapter Five

Research Issues in Hypertext for Learning

5.1 Introduction

Hypertext is discussed in this chapter because it is the most widely used form for navigating the Internet and is used for the learning environment for this project. The efficacy of hypertext for learning remains unproven, as is its application for promoting learning via the Internet. Issues which affect conventional hypertext and learning, will also have an effect on hypertext WWW educational environments. It therefore seems to be of great benefit to consider research issues for hypertext when designing WWW systems.

This chapter will examine several areas of hypertext, from general problems such as disorientation and navigation, to specific problems encountered when using hypertext for learning. It will be shown that there is a guidance requirement for hypertext placed on the Internet, and specific methods and tools are able to provide this guidance.

5.2 Definition of Hypertext

‘Hypertext’ has been described in many ways. Nelson (1980) viewed it as ‘non-sequential writing’ in the 1960s, with a system called Xanadu comprised of linked ‘nodes’. But the design of a hypertext-like system was created earlier by Vannevar Bush (1945).
The definition of hypertext has continually changed so that it is more of an encompassing 'umbrella' term for other types of non-sequential systems. Rada (1989) defines it in more technical terms, as 'text database + semantic net + interface'. But there has been a blurring of concepts, with hypermedia and multimedia being regarded as the same as hypertext.

Harland (1992) suggests that hypertext should be solely applied to text. Therefore the term should only be concerned with the inter-relating of individual 'chunks' or files. To apply the term to any system that incorporates any other type of media such as sound and graphics is seen as cognitively changing the interaction between the learner and the medium. It is argued that text is essentially a two dimensional form of communication and the type of cognition that occurs is linked to this plane, whereas graphics and sound is three-dimensional. In the latter, there is more possibility of subjective perspectives, therefore there is a greater likelihood that the design will be unstable and the results unpredictable.

Kahn (1989) suggests that it is important to distinguish between hypermedia and multi-media. A multi-media system delivers information in several forms such as graphics, audio, motion video and sound. Hypermedia implies that the computer system supports persistent links between elements contained in the media. The unique characteristic of being able to follow links is therefore retained.

In this research, hypertext is seen as non-sequential text with non-animated pictures. The linking between the nodes define the unique characteristic of hypertext; of being non-linear or non-hierarchical (Angelides and Tong, 1995). Another characteristic is to allow users of hypertext to browse, absorbing the information at one node and seeing what links are attached to that node, reflecting the definitions given by Nielsen (1990) and by Conklin (1987):

"The basic idea of hypertext, after all, is that ideas correspond to perceptual objects, and one manipulates ideas and their relationships by directly manipulating windows and icons".
5.3 The Characteristics of Nodes and Links

Nodes are elementary or base units of information that can take the form of chunks or fragments of text, graphics, video and other forms of information. Nodes are designed to reflect the reader's information seeking goals and will vary in size from a single part of a display to a multi-screen document (Tomak and Maurer, 1991). In other systems these nodes are also described as cards such as in Hypercard systems (Goodman, 1987) or Frames, such as in KMS.

Some systems allow the learner to change or create new nodes but the majority do not. The reasons is that the learner may not do so efficiently in terms of providing any additional benefit to the learning process; either because they will create the same information but in a haphazard way, or have insufficient understanding of the domain to do so. Jones (1989) suggested that allowing students to use a system with limited annotation capabilities could still provide flexible browsing and help them to orient themselves to the domain while simultaneously giving students a feel for the system.

Nodes are used to represent a singular concept or idea that the author wishes to put across. The node from which the link originates is referred to as the reference node, and the node at which the link ends is called the referent node. Both the references and referents are anchors with a link determining the relationship between the two anchors.

Links allow the learner to traverse from one related node to another across the information space, a document universe of information or a 'docuverse' (Nelson, 1987; Tomak and Maurer, 1991). Links are associative in that they define the associative relationship between the pair of nodes that they are linked to. They provide structural information about the domain and the way that it is organised. They can also represent semantic meaning by being typed; in that they can have varying levels of details, propositions, summaries and other types of information included.

Most hypertext linking methodologies lack any formal structure in terms of the relationship between the links (Bloomfield and Johnson, 1993). In terms of linking,
most hypertext systems fall into the following categories: (a) those with simple associative linking (e.g. Intermedia), (b) those with domain-specific relations which have names distinct from the text (e.g. THOTH-II, Guide 3.0), (c) systems that incorporate AI methods or sophisticated searching mechanisms (e.g. Expertext) and (d) those systems with domain-independent links (e.g. Textnet). Some of these systems will be discussed in the next section. For a description of the relations between links, Bloomfield and Johnson (1993) provide a comprehensive description of domain-independent linking with a need for a domain-set of empirically derived and cognitively salient relationships to aid user navigation and comprehension. For a discussion of the issues related to linking from an information retrieval perspective, Tomak and Maurer (1991) provide a comprehensive discussion of link filtering and ranking.

Therefore the behaviour of the user is to move from one node to another by following links or creating new links themselves. A node is a particular point in the hypertext, with links creating a relationship from one node to a related other. This suggests to the user a particular reason for the link and displays the structure of the domain.

The destination of the link can be a particular point, a completely new section or multiple windows. Browsing in a non-hierarchical manner is characteristic of a hypertext environment, with the learner traversing a whole network of interconnected nodes.

Browsing in hypertext systems is defined as visiting a set of related nodes through transversal of links. This is in contrast to retrieval by queries based upon keywords or field-value pairs (McAleese, 1989). The browsing process allows users to explore the knowledge domain or database, to learn about related concepts and to refine their information goal as they learn more through exploration. The iterative refinement of information goals can be useful in situations where the user would initially have trouble formulating a useful query. Thus in browsing a hypertext, the user is dynamically building a model of the structure of the information which may not be explicitly present in the information space itself. In searching, the user has to understand something about the structure of the information space before starting, and the system uses this structure to respond to the user's query (Rada, 1995).
The problem of increased flexibility of access by browsing is, however, an increased
cognitive load on the user, which results in the disorientation problem. The cognitive
demands of making many levels of navigational decisions while trying to integrate the
contents can be cognitively demanding with users having difficulty deciding what to
read next.

In terms of browsing strategies and user goals, several classifications have been put
forward. Canter et al. (1985) determined five browsing strategies of scanning
(covering a large area without depth), browsing (following a path until a goal is
achieved), searching (locating using explicit goal), exploring (finding the extent of
information), and wandering (unstructured journey through the information).

McAleese (1989) applied these strategies specifically to a hypertext context and
discussed how different interfaces could foster different browsing strategies. Embedded links, where the links are embedded in the views of the node contents, can encourage scanning and browsing strategies. Maps, which provide graphical representations of node-to-node connectivity, are more suited to seeing the extent or breadth of information. In situations where the user had a specific goal which is describable in terms of node characteristics, using a query mechanism instead of hypertext browsing would be more efficient.

The next section will discuss technologies that have contributed to the features of
current hypertext systems. This will serve to highlight particular theoretical strands
and difficulties which will re-appear in the discussion on hypertext issues specific to
learning (section 5.7).

5.4 Traditional Hypertext Systems

The structure of hypertext systems has previously appeared as paper-based systems.
The structure is similar to paper-based concept maps that have been used for many
years in classroom teaching (Novak and Gowin, 1984), whereby the learner forms
maps which display how one concept is linked to another. In terms of technological innovations in hypertext there are several key system developments.

Bush (1945) proposed a device termed the Memex (Memory Extender) in which an individual stores all the items of information in miniaturised form on film and which allows one item to be linked to another. The machine would then allow the reader to view an item, point to links and retrieve further items. This was one of the earliest descriptions of a system fulfilling the particular hypertext characteristic whereby the selection of one item will bring the user to another item. It was supposed to support connections that were part of the mental process of intellectual enquiry.

NLS by Engelbart (1963) was one of the earliest systems to display hypertext functionality, and was modified to become Augment; a system to store items that were referenced to one another. This system demonstrated how people could use systems to work with ideas, such as supporting the recording of links between ideas.

Already mentioned is the Xanadu system by Nelson (1980). The idea was for a 'docuverse' whereby the user was able to follow links across different documents and also to different systems. The docuverse was to consist of possibly billions of textual material, cross-referenced and uniquely stored as one item regardless of its appearance in other documents. Nelson’s term “hypertext” reflects the character-oriented view at the time, with this application to graphical user interfaces taking place in the 1980s.

Intermedia (Meyrowitz, 1986) provided a graphical browser, the web view, which automatically generated a non-hierarchical overview of the links. This view displayed those documents which were linked to the current document as well as a list of each document the user had read, called a path. This was to aid the users in overcoming the problems of where to go and where they had just been. Whether the link structure was visible or not, the promotion or enforcement of the hierarchy by the hypermedia system implied a particular meaning in trying to understand the domain. Links in Intermedia had no system-defined hierarchy and were bi-directional; hence allowing the user to browse in a non-hierarchical network structure. Also the authors who built Intermedia learnt as much as those who had used it, in terms of understanding the
The application of a semantic network approach was seen in Notecards (Halasz, 1988). It was composed of notecards similar to Macintosh HyperCards (Goodman, 1987) connected by typed links, and they could contain text, graphics and other forms of media. A browser would display the node-links of certain parts of the network and the system could be integrated with other large systems.

In terms of providing authoring capability in hypertext systems, Knowledge Management System (KMS) provided similar functions to Intermedia (Kahn, 1989). A KMS frame is a fixed size, in terms of the size of a node, and could contain different types of media. It did not display an overview, but it did support a parent-child relationship between frames, which encouraged authors to develop documents as hierarchical structures. Also, as in Hypercard discussed later, a branching sequential path among nodes was encouraged with one set of information being replaced by the next set, rather than overlapping windows such as the Guide system. The system encouraged the reader to add or modify the material, as well as make links. Like Intermedia, KMS gave readers “annotation privileges” which was regarded as important for promoting student interaction.

Guide (Brown, 1987) presents one or more documents as overlapping parts of the same viewing screen. This meant that links could be made with finer granularity, and it opened up the possibility that a link could be designed that allowed the user to have visual contact with both the reference and referent document at the same time. An individual document could be much more complex than in the Hypercard or KMS system, as it could allow any number of nodes connected to a single node in any amount of documents.

Hypercard (Goodman, 1987) on the Apple Macintosh computer is composed of documents which are constructed in layers to conform to the size of the smallest Macintosh monitor. The relationship between any stacks of cards in any stack is an arbitrary one but it does promote sequential access, as it is a simple way for the reader to go through a whole stack. Attaching names to the cards and the stacks provides
some ability to tell the reader the current location, with navigation buttons and fields simplifying navigation. Essentially a link was an instruction to the system to dismiss the current screen, but the granularity, as in KMS, has been designed to be coarse, going to whole documents rather than smaller sections. Like KMS there is the encouragement to follow a branching sequential path among nodes, following the next frame or card.

5.5 Categorising Hypertext Systems

There have been many propositions put forward for classifying hypertext systems. In terms of educational hypertext this has been partly discussed in chapter 2 with Ferguson (1992) classifying systems in terms of degrees of learner control, and Mayes et al. (1990) highlighting a consideration of the type of learning that the system is supposed to support. Conklin (1987) provides classification in terms of many dimensions, which are useful in determining where hypertext systems fit in and how new ones could possibly be built.

Conklin classified hypertext systems into several categories: (a) macro literacy, (b) browsing systems, (c) exploration and (d) general systems.

(a) Macro literacy systems provide storage and retrieval of vast amounts of information and can, for example, be collaborative hypertext environments that can allow users to compare loosely structured information such as in Xanadu (Nelson, 1980) or Textnet.

(b) Browsing systems can be viewed as reduced versions of Macro literacy systems with particular attention paid to providing users with an easy to use interface.

(c) Exploration systems are used for problem solving by bringing together disparate facts and other pieces of information to solve the problem goal.

(d) General systems are general use systems and can be used as research tools such as NoteCards (Halasz, 1988).

This method by Conklin provides one method for categorising systems. Halasz (1988) classifies hypertext systems in terms of generations. With the first generation
of systems being prior to 1980 focusing predominantly on group work. The second
generation concentrated more on single-user interaction, with graphical visualisation
and increased interface design for primarily research purposes. The third generation
moves towards collaborative interaction and other areas such as adaptive hypertext
and web-based technologies (Brusilovsky 1996, Ibrahim and Franklin, 1995).

What is apparent is that there is a need to consider many dimensions when attempting
to categorise hypertext systems. They differ according to the goal that they are to
achieve, and the perceived importance that different researchers have attached to
specific dimensions.

5.6 Current Research Issues in Hypertext

There continue to be many research issues in applying hypertext which remain
unresolved and which impact different domains according to the goals of that domain.
For example, the problems faced in using hypertext in decision support systems
(DSS) is different from those of educational applications of hypertext (Marakas,
1995). In DSS there is a concentration on the evidence and the validity of the
information when making a decision. In education there is less of a need to know
where the information has come from because it has been provided by the author or
teacher in the material. Therefore the purpose of the hypertext system determines
how important some research issues are over others when designing the system. The
strength of hypertext is in the ability of the user to navigate in a non-linear,
exploratory manner but this is also where many of its problems lie.

In terms of the use of hypertext, this thesis examines how to alleviate the navigation
and disorientation problem but only as part of a wider approach for making hypertext
beneficial for learning. Navigation and disorientation contribute to part of the
symptoms of an instructionally ineffective learning environment. In this respect
investigating this issue will help to determine principles for encouraging structured
learning whilst maintaining the freedom to explore in a hypertext environment. This
is something which appears as a paradox between the exploratory behaviour that hypertext encourages and the guidance that the teaching process seems to require.

5.6.1 The Issue of Disorientation and Navigation

Disorientation during the navigation process and cognitive overload are two key issues in determining the efficacy of hypertext. The problem of disorientation in hypertext will usually result in a marked decline in the performance of the user. This is the "lost in hyperspace" problem, coined by Conklin (1987). Edwards and Hardman (1989) classify this into different forms: (1) not knowing where to go next; (2) knowing where to go but not knowing how to get there; (3) not knowing the current position relative to the overall hypertext structure.

Disorientation while browsing can lead the user to miss out sections of the text and open the same few nodes repeatedly. This will also be reflected in increased time taken to locate the relevant information, showing a non-optimal route through the hypertext and difficulty in being able to formulate search requests (Edwards and Hardman, 1989, McDonald and Stevenson, 1998, Kim and Hirtle, 1995).

There has been much research into the use of hypertext systems from an information retrieval angle, and less so to systems for learning. Such a research area is the "lost in hyperspace" problem, which is a description for a whole list of problems that the user may experience. Conklin (1987) cites disorientation as one of the major problems of hypertext. He divided this problem into two areas. These are the problems of the user not knowing the current position, and how to get to another point in the hypertext. Exacerbating this is the users' feeling of not being aware of what is in the immediate vicinity of the current node. It can be summarised that the user does not know "where" and "what" to look for next.

Landow (1987) claims that:

"simply linking one text to another in some cases fails to achieve the expected benefits of a hypertext system and even alienates the user".
This alienation is caused by the user being unable to see why two nodes are related and because, even though they have followed the link, the referent node has taken them to an unexpected piece of information.

Bloomfield and Johnson (1993) argue that the addition of more information to the links between nodes will help to alleviate these problems; and that these can be added to be generalisable across many information domains. The main benefit will be to provide the user with greater knowledge of the information content of the nodes most directly related to the current one. They are carrying out research into providing a set of hyperlinks which combine a high degree of meaning (or cognitive salience) with independence from the information domain. In terms of learning, an additional benefit may include faster learning times for new hypertexts arising from the same links being usable in many information domains. This is a way to support learning at the link level; but is just one of many methods for supporting navigation and structuring of the information space. To minimise the negative effects of disorientation, navigational aids have been developed.

There will be a discussion of the more popular navigational tools to determine the effectiveness of these in alleviating user disorientation and therefore reducing cognitive overload. In particular there will be a focus on graphical-based aids such as maps as these seem to hold particular advantages when applied to using hypertext for learning; in terms of cognitive support for the exploratory process.

5.6.1.1 Graphical Browsers

Graphical browsers are used to provide overviews of hypertext. Intermedia (Meyrowitz, 1986), NoteCards (Halasz, 1988), gIBIS (Conklin, 1988) and other hypertext systems use these graphical browsers to help users develop a mental model of the information in the system, and maintain a sense of orientation during navigation through the hyperspace. These mechanisms provide a two-dimensional display of the hypertext network. They also serve to minimise cognitive overload by showing a small part of the network and allow the user to estimate how many nodes and links are
contained by giving indications about the size. Some of these graphical overviews are generated at runtime and make links visible by drawing lines between nodes.

In Intermedia (Yankelovitch, 1988) used the "web" concept to provide both temporal and visual aids to assist the learner in navigation. A web is a network of documents or portions of documents linked together. It was determined that disoriented users needed a sense of location and context. Therefore spatial information, such as "Where can I go from here?" was accompanied by temporal information in terms of "How did I get here?" As links are added they are automatically updated. Therefore the map component of the web acts as a spatial representation of all the links associated with the currently activated document.

5.6.1.2 Maps and Overview Diagrams

Maps provide a spatial context for a hypertext network. Because they are dynamically updated, as previously mentioned in the Intermedia system, the correct information is always available.

These overview maps are also called 'global maps' in Intermedia and a 'browser' in NoteCard (Halasz, 1988). They are useful only if the hyperspace is not too large, otherwise they become too difficult to read due to problems such as screen size or an over-complex display. But as De Young (1990) argues, there are limits to the effectiveness of graphical representations if the underlying structure of the hypertext is ill conceived:

"But if a hypertext system is a densely connected, unstructured graph, no presentation of the mess is going to clean it up or make it conceptually easier to understand".

Overall, maps or overviews at both the local level and the global level are regarded as beneficial aids for supporting navigation. Global overview diagrams provide an overall picture that can be used as anchors for local overview diagrams. Monk et al. (1988) showed that even static, non-interactive graphical representations of the hypertext structure is beneficial, although Nielsen (1990) argues that if the diagrams are too large they may introduce navigational problems themselves.
5.6.1.3 Paths, Trails, Guided Tours and Tabletops

Readers have a problem understanding the presented material because they view it in the wrong order. Paths overcome this problem by allowing authors to add an appropriate order of presentation for a specific user. There are two specific types: a history trail that logs every location visited and a guided tour with a predetermined set of locations which the author has predicted as those useful to follow. The difference is that history trails are those of individual readers and act as a personal reminder, whereas guided tours are those predetermined by an external source, usually the author or teacher.

It was suggested by Bush (1945) that Memex should support trails. In Intermedia (Meyrowitz, 1986), a path is a list of documents a reader has visited in one session. The display of this path consists of the document name, an icon indicating if it has been opened and a timestamp of when it had occurred. When the user exits the system, the path is saved, and when re-opened it is restored (for evaluation and as a reminder).

NoteCards also contain guided tours (Halasz, 1988) which are a navigational tool controlled by the system which can be entered and exited according to the reader. It can be accessed via a graphical browser and is composed of tabletop cards. These are screens of information that have various data such as screen positions, scrolling locations and the order that the windows have been opened. Work by Hammond and Allinson (1988) found that those unfamiliar with the material being taught found guided tours of most use. But Nielsen (1990) regarded this navigation aid as limiting the purpose and potential of hypertext in that it limited the reader's freedom to explore. It can be concluded that different levels of guided tours can support different types of users and paths can support exploratory browsing rather than replacing it. The user temporarily gives up the flexibility of open exploration for less disorientation.

5.6.1.4 Historical Aids

History trails, landmarks and footprints are navigation aids related to the temporal context of the hypertext, answering the question of what has been seen and what
needs to be explored. These have greater importance in educational hypertext with the suggestion that they can be used as adaptive navigational tools (La Passardiere and Dufresne, 1992).

History trails allow the user to browse past activity and provides specific support in opening previously read documents. In Intermedia this is provided by the web view’s path which is a simple linear list of the user’s activity. In KMS (Kahn, 1989) the solution for backtracking is different allowing the back command as one of the mouse buttons.

Footprints are system marks which are automatically updated as the user passes through them. Landmarks are annotations added by the user which can be used to highlight important information. Progression cues are less used and serve to present a visual indication of what the user has already seen; as in the ELM-ART system which shows progress for each chapter of information encountered (Weber and Specht, 1997). Hotlists or Bookmarks included in most Internet browsers (Brusilovsky and Pesin, 1995) can be regarded as landmarks and history trails as they allow access to previously read web pages as well as provide records that the user can choose to keep.

5.6.1.5 Indices and Contents Listings

Indices and contents lists are used in traditional text as a means of assisting users to gain an overview of the breadth of material covered in the document and to find specific information within the text. Both of these aids are used as a means of assisting hypertext users when searching for information. McDonald and Stevenson (1998) have reported the effects of this in their review of navigational tools, concluding that the provision of a content page improved both navigation and memory for text topics.

5.6.1.6 Fisheye Views

These can be integrated as part of local maps. Similar to a photographic lens, information of interest is at the centre; with those of less interest being on the periphery (Furnas, 1986). These Fisheye views have been seen as of use for exploring
large nested hypertext networks. The difficulty is in defining the distance to a node from the current position and defining a way to display different levels of detail (Nielsen, 1990).

5.6.2 Navigation in Terms of Conceptual Space

Some research has suggested that a certain level of disorientation and cognitive overload will facilitate exploration and learning. The suggestion is that there has been a lack of investigation on navigating through the "conceptual space". As Mayes et al. (1990) suggests, following links to nodes provides very little useful understanding in terms of effective learning as it only serves to tell users where a particular piece of information is located. Their Strathtutor system provided links which were based on how the nodes were related to each other conceptually and they viewed "what to do next" questions as being able to enrich the learning process. This has been discussed further in Chapter 3 on Guided Discovery Learning.

5.6.2.1 Comparisons on the Effectiveness of Navigational Aids

Users need to perform navigational tasks such as determining which node to visit next, the current location and also executing that selected route. This is added to the need to carry out informational tasks such as summary, analysis and comparisons of the relationships between the nodes; needed for understanding and carrying out multiple tasks. This leads to an increased load upon the learner's cognitive resources, termed "cognitive overload" with subsequent navigational, informational and task management becoming increasingly difficult to maintain (Conklin, 1987).

In terms of learning from hypertext Halasz (1988) argues that completely free exploration of a network of nodes and links will be inefficient and detrimental to learning. Learners will fail to gain an overview of the material and will find it difficult to locate or comprehend the amount of information available. Navigation and orientation in Hypertext have often been tackled by the provision of graphical representations of the underlying information structure of the hypertext document.
Graphical browsers portray the author's view of the information space which may not necessarily reflect that of the user (McKendree, Reader and Hammond, 1995). Allowing the user to annotate and change links can be a possible solution, but providing this facility can increase cognitive load; with the user having to carry out multiple tasks. In educational tasks, which are concentrated on learning rather than information retrieval, this could lead to a distraction from understanding the material.

Allinson and Hammond (1989) examined the use and effectiveness of navigational tools. The tools consisted of guided tours, an index and a map. The subjects used the tools extensively and in a task-directed manner. The map was used during the browsing phase, and the index for information-seeking tasks. Therefore there seems to be a need for such navigational tools but at different stages of the task that the user is attempting to achieve. Edwards and Hardman (1989) provide a warning that providing too many navigational tools can themselves cause problems. The tools provide a form of structural information that may not match the actual hypertext structure. This mismatch can mean that a map may serve to make links between nodes explicit whereas including an index will not, providing differing information on the same hypertext.

Therefore these navigational tools can help in browsing but it is also suggested that just providing access to the information is not enough. Without clear navigational semantics, knowledge of what the system contains, how the information is related to each other; and different ways to approach the same material in a learning context, the user will find hypertext difficult to use for learning. Navigation should not be concerned with just the traversal of links but providing a way of showing a specific approach to tutoring. Embedding a tutorial component controlling navigation and presentation remains under-developed in hypertext research.

As Van Dam (1988) suggests, using AI in navigation would allow systems to infer whether the information at each node is relevant to the user at that particular time. There is a specific discussion of cognitive tools in this chapter (section 5.9) which provides suggestions of tools that ameliorate cognitive overload and disorientation specifically for hypertext in a learning context. This section has discussed issues
which have continued to plague the effectiveness of hypertext, namely these of
cognitive overload and disorientation, and outlined major navigational tools which
have been used. The next section will look specifically at hypertext for educational
applications, to determine issues relevant to this specific use of hypertext.

5.7 Hypertext for Educational Applications

Hypertext is appealing for educational application because it maintains the freedom of
the learner to explore in a self-directed manner, traversing through a self-selected path
of interconnected nodes of information. Learners are able to follow their own goals
without having to follow pre-determined paths of the authors or course instructors.
This learner-led form of instruction is claimed to lead to deeper levels of learning, as
the learner learns less by being told (Harland, 1992).

Educational hypertext has been used to supplement or support traditional computer-
assisted learning (CAL) or Computer-Assisted Instruction (CAI) techniques as well as
traditional classroom practice. Not all tutorial CAI is the substitution of classroom
instruction by computer instruction. It is more common to integrate short CAI
tutorials on specific topics into an overall course delivered by the teacher. Therefore
it makes it difficult to separate any benefits of CAI over alternative instructional
designs. What can be measured is the overall effect of a combination of teacher-led
and CAI in tandem, rather than the teacher alone or the CAI alone. There is also the
criticism of much less formal research, with too many uncontrolled variables in a
classroom scenario (Romiszowski, 1992, Entwistle, 1992). This section examines the
problems that are specific in using hypertext for learning and provides a discussion of
the difficulties in evaluating the success of such systems.

The popularity of using CAI has grown, although not to the degree that was
previously predicted (Entwistle, 1992) and it is predicted that it will continue to do so
with the exponential growth of the Internet (Debreceny, Ellis and Chua, 1995). The
suggestion for the future is that whole lessons taught by lecturers can be replaced by
using the Internet to implement them, with hypertext gaining greater consideration as

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This thesis contributes to principles which would allow hypertext to be made more beneficial for promoting learning.

The aim of this chapter has been to assess the potential of hypertext for learning by reviewing the research in this area. The conclusion reached is that there is no instructional design theory which can provide conclusive evidence of the best way to design hypertext systems for learning and that there is a marked paucity of overt pedagogical strategies in the design of many of these systems, which would best promote learning. The next section is a discussion of the placement of hypertext in relation to other CAI systems.

5.7.1 Characteristics of Hypertext in relation to other CAI

Although traditional CAI programs have changed from their early focus on branching and drill-and-practice, a semblance of them is still being used; usually as a mixture of both types. These are often in the form of question-and-answer sessions. Although more versatile than previous drill packages, because they have better feedback and there has been a conscious effort to develop mastery of specific objectives, these remain lacking in learner-led instruction (Romiszowski, 1992). Some of these systems have been supplemented by a hypertext component, adding navigational aids such as guided tours.

In terms of ITSs, the application of AI has provided some research into questions that focus on the role of the learner in the instructional process. A key feature of such systems is the design of user models to attempt to track the progress of the learner and the use of such models to determine the actions of the tutorial component. But Hammond (1989) has argued that this reliance on comparing user models, usually in relation to expert models, can severely restrict the ability of the learner to explore freely. Therefore there is still debate over this "intractable" student modelling problem (Self, 1990) which has remained unresolved. Other difficulties lie with representing domain knowledge in a way that can make it adaptive to a wide range of domains, and are still being researched. What is apparent is that there are educational benefits in explicitly representing some of the underlying knowledge structure (Wiles and Wright, 1997; Shapiro, 1998). Wiles and Wright, (1997) argue for a constructivist
approach to designing hypertext for education where there is a need for a shift in traditional methods for education with:

“Emphasis placed on discovery and experimentation, with learners applying their revised ideas ... where they can be reinforced, rather than simply absorbing facts and figures”.

The development of advice-giving systems and guided discovery techniques provide a possible way of overcoming this model-driven system of control that ITSs have continually relied upon (Elsom-Cook, 1990). Therefore a move has been from tutoring systems that are prescriptive, to ones that take a more advisory role. Research into exploratory systems allow a certain degree of tutorial and learner-led control, but the degree that this should take place remains contentious. Hypertext, in contrast to traditional behavioural CAI and model-driven ITSs, supports the shift towards exploratory learning. When applied to a learning context, the strength of hypertext is because it allows the possibility of freedom and guidance in the educational process. Traditional CAI provides systematic, linear forms of learning but hypertext can allow the user to select the path that is taken. This is the main postulate of this thesis, to explore beneficial ways that guidance techniques can be built into the system: an area in which unstructured, non-adaptive hypertext is insufficient in supporting learning.

5.7.2 Obstacles to using Hypertext for Learning

Hypertext systems allow the potential for learning for several reasons; they allow a high degree of learner control, create a change in the role of the teacher in relation to the learner, and provide a cognitive approach to the educational process which previous CAI lacked (Marakas, 1995, McKnight et al., 1991). There is also the suggestion that attention must be paid to two related areas, the process of learning itself rather than just the learning outcome (Marchionini, 1990).

In terms of the learning process, hypertext has specific problems related to this purpose of use. That of being lost in the material, cognitive overload when there are too many tasks to carry out and unclear educational goals (Conklin, 1987). The
interface itself can add to the cognitive overload that the learner experiences (Rappin et al., 1997), whereby design decisions have to be made over making software easy to learn but not so easy that the system carries out tasks that the learner would benefit from doing. Too many navigational tools may prove to be detrimental to learning, providing more facilities than necessary (McDonald and Stevenson, 1998).

The control aspect in hypertext shifts the onus from the system to the learner; to allow the user to determine the navigational path following nodes perceived as being of relevance to the current task. This again further adds to the cognitive overload as the learner may follow “blind alleys” or adapt misconceptions that become difficult to change.

It is regarded that allowing the learner to freely explore the hypertext does not necessarily reflect a gain in learning (Halasz, 1988). Individual learner differences of will influence whether they can derive the relational structure that is embedded in the organisation of the concepts in the material. Some educational systems lack this ability to integrate concepts into a cohesive enough form to provide the user with a perception of the whole structure (De Young, 1990; Kommers, 1990). Those who know the domain will have less difficulty navigating than those who do not; but unstructured hypertext is most detrimental to learning if there is no navigational support. The inexperienced user will face the most difficulties (McDonald and Stevenson, 1998).

There is evidence to suggest that hypertext is able to support learning. The requirement is for additional tools to be included such as navigational tools (La Passadiere and Dufresne, 1992), cognitive tools (Kommers, Jonassen and Mayes, 1992) and limited learner authoring of links and material (Bloomfield and Johnson, 1993). These types of tools can be regarded as part of providing less interventionist forms of tutoring, in some sense to be a type of “soft tutoring”. The aim is to move away from a model-driven form of tutoring with all its criticisms of inaccurate student modelling and constrictive control. Some hypertext-based learning systems allow the learner to temporarily give up the flexibility of open exploration for less disorientation (Hammond and Allinson, 1988). Therefore the learner consciously gives up control to the system in situations where it is unclear what is to be learnt or where to go.
Although imposing a semantic structure on a hyperdocument can help to alleviate navigation problems, it is argued by Duffy and Knuth (1990) that passive hyperdocuments are only suitable for students who have a strong understanding of the subject domain. Students tend to be passive learners so a hypertext-based system needs to include active tuition (Edwards, Powell and Palmer-Brown, 1995). It is the intention of this thesis to show that there is a need to have an active teaching mechanism within hypertext that can aid in the conceptual understanding of the knowledge domain being taught.

This is an issue related to a main hypothesis in this experiment, that of providing the correct level of instructional guidance by using system control. With hypertext learning environments, control can be over material sequencing, learning activities such as testing, and more overtly such as system messaging. Determining a suitable level of control is dependent on many factors such as individual learner differences, learning goals and knowledge domain (Hammond, 1991; La Passadiere and Dufresne, 1992). There remains obstacles to learning using hypertext with one of the major issues being navigational disorientation. This is discussed next in terms of navigation and system control as a specific requirement for educational hypertext applications.

5.7.3 Specific Requirements in Education

In terms of specific navigation in educational hypertext there are different requirements from simple information hypertext. The main objective of educational hypertext systems should be to ensure that the user not only sees but also learns a certain amount of relevant information (Jonassen and Mandl, 1990). The interactional potential of hypertext can be used to include testing, knowledge evaluation and specific advice; and is reflected in the system designed for this study. To provide a freedom to explore this must also be coupled with an interface that can provide information in a relevant order and system feedback that takes into account the learner's level of knowledge.

In terms of navigational tools (which were previously discussed in section 5.6.1) these need to be able to help the learner to understand the extent of the information (Kim and Hirtle, 1995) and the learner's position in that information space. Other
researchers have advocated that a form of control may also be necessary (Altamura and Roselli, 1995). As La Passadiere and Dufresne (1992) succinctly point out, to provide a hypertext system able to give didactic advice it needs to offer flexibility as well as:

"act as a guide, as a testbed and eventually as an evaluator, that might be useful for the student and his teacher, to evaluate and to support the learning process".

To be able to introduce structure in the interaction, the provision of navigational tools to display objectives or suggested paths in the material may encourage exploration and learning. For hypertext systems in education to be adaptable to the learner's current level of knowledge there should be the inclusion of testing. It is also necessary to include some level of system control. The control should be based on knowledge of a model of the task, a model of the tutor and a model of the learner's progress. The control has to be well integrated into the explorative environment and it may be hidden (such as a help message being adapted), negotiated (by asking if there is a need for further information) or displayed in the interface (such as shaded menu items to show inaccessibility at a particular stage).

Browsing has been continually regarded as a means of referencing. Approached from a data retrieval angle, and this has led learning and comprehension to be placed into a lower priority (Harland, 1992). In terms of needs specific to educational hypertext, if learning is to be more than superficial, so that the learner has to acquire and apply problem-solving and inferencing skills, it becomes important to guide the learner by providing some form of diversified didactic support; such as offering advice adapted to level of progression. The relational nature of hypertext can make it into a tool that can be used to increase the learner's knowledge; creating a shift to focus on learning and discovery of meaning, rather than just providing information for the reader to browse.

5.7.4 Evaluating Hypertext for Learning

Methods for evaluating the effectiveness of hypertext for learning remain lacking and guidelines to carry out an evaluation remain open to controversy. Although there are
results to suggest that hypertext is able to promote meaningful learning, there is no established psychological theory for the design of such systems (Knussen et al., 1991). Another criticism is that many of these hypertext systems are research tools, mostly tested in laboratory conditions rather than real classroom settings (Entwistle, 1992).

Other researchers dispute the use of the analogy often drawn between the way the brain operates and the structure of hypertext; arguing that the structure of memory is too poorly understood to contribute to the design of educational hypertext system (McKendree, Reader and Hammond, 1995). Therefore the effectiveness of hypertext for learning remains lacking in findings. The following section will critically evaluate current systems comparing linear and non-linear modes of learning, the provision of support for learning and using semantic networks.

5.7.4.1 Lineal versus Non-Lineal Thinking

This attempts to investigate the paradox which exists in education of attempting to foster non-lineal thinking using linear communication, presentation and instruction often as books. Beeman et al. (1987), suggests that hypertext provides a solution by being able to encourage non-lineal thought. The lineal style is one of rote memorisation and drill-and-practice, used in education not only for the memorisation of facts but also the promotion of metacognitive skills and other higher thought processes, whereas non-lineal thought is concerned with the acquisition of pluralistic or critical cognitive styles of thinking.

The Intermedia Project (Meyrowitz, 1986) attempted to promote non-lineal thought but the results were inconclusive. Improvements in learning may have been caused by other factors related to the introduction of hypertext rather than the actual medium itself. For example the lecturers had to re-design the course notes for conversion into hypertext, hence the learning material had been improved. This circularity of results, whereby the design of the materials was geared towards the assessment procedures, meant that they were not a reflection of conventional courses (Entwistle, 1992). Therefore the results could indicate a change in the course rather than a marked change in thought processes. These results did suggest some improvement in critical
thinking and some students developed analytic skills. But there was no evidence that any non-lineal skills that were picked up were transferable to other domains (Beeman et al., 1987).

This study provides an example of the difficulty of introducing a new technique or technology into an educational setting outside of the laboratory. Therefore it seems desirable, when developing hypertext materials, to pay attention to a realistic educational setting utilising currently available classroom materials. Work by Wellington (1995) highlights the small number of actual evaluations that have taken place concerning hypertext for teacher education, arguing that:

"there has perhaps been some research through a rose-coloured lens, as so happens with new technology" (pp.38).

Another interesting result was that those who produced the material had greater gains in learning and deeper understanding than those students actually using the system, replicating the earlier findings by Mayes (1993).

5.7.4.2 Learning Support Environments

The rationale of many of these learning environments is to use existing knowledge of human cognition to establish cognitive principles that are applicable to a computerised environment. It has been regarded by some researchers that educational theory is insufficiently developed to provide a model of the detailed processes involved in learning. What are more developed are some principles that can provide optimum conditions for learning. The lack of psychological knowledge has been cited as part of the reason why hypertext may not be as beneficial for learning as others have suggested; due primarily to misleading theoretical assumptions in hypertext research (McKendree, Reader and Hammond, 1995; Tergan, 1997).

Hammond and Allinson (1989) provided findings that hypertext can act as an exploratory environment but that there is a need for the inclusion of some form of guidance and navigation support. In their two-year study of undergraduate usage of the Hitch-hiker's Guide, which used the metaphor of a travel holiday, appropriate
navigational tools were able to provide enormous potential in future computer learning systems.

These tools included guided tours, maps and an index to compare against a pure hypertext system. What was apparent was that all the tools were extensively used even by novice users of such facilities, with fifty seven percent using all the tools; and it was ascertained that certain tools could be particularly beneficial for specific tasks. Exploratory tasks resulted in a greater use of tools for browsing (e.g. tours), whereas directed tasks resulted in a greater use of tools for supporting searches (e.g. index). Further support for the use of navigational tools came from the subjective questionnaire that was also administered along with an analysis of the navigational log files.

A further examination of the exploratory task condition in Hammond and Allinson’s study, concluded that subject’s perceived coverage of the subject domain was unreliable in the hypertext only condition. Those without a map facility overestimated what they had covered. Maps are therefore able to provide a simple representation of the knowledge structure and help to address problems of “Where am I?”, “Where have I been?” and “Where else is there to go?” Therefore the aim of learning support environments is to provide flexibility and freedom but to maintain structure and more directed exploration of the hypertext learning environment, with the inclusion of navigational tools.

5.7.4.3 Semantic Networks and Web Learning

The paradox between the promotion of non-lineal thinking using lineal methods has been apparent to other researchers in hypertext. Jonassen (1986) suggests that hypertext is able to provide a move away from the sequential processing tendency whereby learning is often in a linear, structured fashion. Later work by Jonassen (1990) suggests that when designing hypertext structures, these are able to reflect the semantic knowledge which the learner is to learn.

The general semantic model is a graph structure consisting of a web of nodes and links. The nodes and links of semantic networks can be used to provide descriptions
of what the learner already knows and what is needed to be learnt. Like semantic networks, hypertext nodes contain information, and correspond to articles or other information units; while links represent the connections between them. A reader interacts with the hypertext by following links. With this approach, the learning process requires the learner to construct new nodes and to inter-relate them to previous nodes. This is similar to the idea of 'cognitive anchors' (Piaget, 1965) included in the learning environment; whereby familiar knowledge can be attached to new information.

The web teaching principles begin with instruction in the form of a web of information which outlines the topics that need to be discussed and which serves to provide an overview of the domain. This follows down to substructures which contain more detail as the user progresses through the web. The importance of this approach is that the underlying principle assumes that the structure of the hypertext represents such a web of interrelated concepts.

Criticisms of this approach are that there are no established methods for being able to represent the knowledge structure of the subject domain, or the knowledge of the learner in relation to this. There are criticisms that human semantic knowledge structures are too complicated to be captured by the web structure of hypertext (Tergan, 1997). In addition, although the learner is given some freedom to interact with the subject domain, this type of instruction is teacher-led. The system determines the web of knowledge that the user has to explore and makes assumptions about what the learner knows and what is needed to be presented. This is in contrast to Jonassen (1986) arguing that it should be the learner who determines the relevancy and sequencing of the information as part of passing the locus of control to the learner.

The use of concept maps to 'map' learning and to structure the learning process has been examined in a hypertext environment. Generally it has been shown that the embedding of a concept-mapping tool can provide learning benefits for certain tasks. This evidence is fully reviewed in section 5.9 examining cognitive tools for learning. The implications of using such a tool are part of the research issues addressed in this thesis. It is suggested that the tool can enhance the cognitive nature of the learning
given by using hypertext and that it does so by supporting learner's exploratory
behaviour. A more positive outcome in terms of learning outcome and user
satisfaction is predicted to be achieved by adding the cognitive tool to a guided
component to formulate a hypertext learning environment.

5.8 Issues of Control

Hypertext can allow for non-linear exploratory approaches to learning. This is
considered to be superior to learning from linear modes of presentation. Allowing the
learner the option of greater autonomy determining where to go and what is learnt
encourages exploratory behaviour. Therefore, if following this line of approach, the
learning environment should be flexible enough to allow learners to self-determine
the structure of the material and the sequencing of the presentation in order to adapt
the material to best suit their own perceived needs.

Some research results have suggested that providing freedom, in a non-linear
condition, can improve performance. Other systems purposively ensure that no
sequencing is enforced such as the Mayday system which allows students to take the
modules in any order without the need to pass specific performance barriers (Sussex,
Cumming and Crop, 1994).

However it is rare for students to have to follow such a rigid prescriptive, linear
approach to learning in the classroom. Therefore the suggestion is that any results
which show improvements in learning outcome may not be directly caused by
learning in a non-lineal environment, but from the learner being given a certain degree
of control when using the environment (Kinzie, 1990). The next section examines the
issue of learner control in a hypertext environment.
5.8.1 Learner Control and System Control as part of an Interventionist Strategy in Hypertext

The issue of control remains an important one in education but it is less clear whether hypertext allows more control than other computerised learning environments. The issue of whether students learn more effectively when they have control over the sequence, content and strategies for learning has been central in computer-based learning (Merrill, 1980; De Corte, 1994) and remains a focus in hypertext research.

A general issue in educational hypertext is whether non-linear processing and flexibility of access promotes self-regulated constructive mental processing and helps in the acquirement of knowledge. Questions related to this are: (a) is learning effectiveness increased with non-linear hypertext documents when studying in a self-regulated mode as opposed to a guided mode, and (b) does hypertext induce learners to adopt a self-regulated constructive strategy? The aim is to determine if and when the system should intervene in the learning process.

Empirical evidence comes from different lines of research. In experimental design, based on experimental studies, the focus is on performance measures. In other types of research this has been on the formative evaluation of students and an analysis of navigational data (Beeman et al., 1987; Cunningham et al., 1993). The results for self-regulated mode versus a guided mode suggests that it may not necessarily result in higher levels of cognitive processing. Tergan (1997) argued that in most empirical studies, non-linear structuring of subject matter in a hypertext format did not improve comprehension and retention of subject matter as opposed to studying of linear text.

The results indicate that although hypertext-based learning may allow a greater amount of facts to be reproduced in terms of recall, text based learning can often result in better comprehension and reproduction of central concepts (McKnight, Dillon and Richardson, 1991). A major result of these studies is that individual differences such as disparate learning goals or motivation can have an overriding and powerful effect which overcomes any structural parameters that hypertext has for effecting performance (Jonassen, 1993). Therefore providing user control over the structure of the hypertext is open to influence from individual difference factors and
does not seem to have a markedly positive effect on promoting learning. The following section will question whether the learner should have control over the linking and sequencing of the material.

In terms of the question of whether hypertext will induce learners to adopt a self-regulated constructive learning strategy, findings have been derived from mostly qualitative data. If the reader is allowed to sequence the material to fulfil perceived goals, then this may promote self-regulation of learning. But it has been suggested that even when learners are given the option of structuring the information they rarely do so.

Beeman et al. (1987) studied students who used the Intermedia system which allowed students to link materials themselves according to their own understanding and to construct individual knowledge databases which could be linked to the hypertext. The system was designed to promote pluralistic non-linear thought, but most students relied on the system to link concepts rather than linking concepts themselves. So following links instead of creating them became the dominant learning style, with evidence to further prove that a constructive learning style was not selected. These results are typical of the effects of hypertext facilities on the quality and type of learning processes found in hypertext-based learning (McKnight, Dillon and Richardson, 1991).

Therefore the amount of learner autonomy is a problematic area. It is claimed that student-led learning encourages meta-learning and the development of metacognitive skills. But exploratory learning behaviour can lead the user to become lost or to acquire unchallenged misconceptions. Therefore the research issue is how to provide a sufficient degree of student control. To maintain exploration but also to continue to orientate the student during the browsing process (Kommers, 1990). This is part of the goal of this thesis, to determine how to provide structure to the learning process and to allow the learner to approach the understanding of the material in a different manner.

If the goal of the learner is to understand information rather than just locating it (Harland, 1992) then browsing needs more explicit guidance and control while
continuing to maintain freedom. Self-regulation is possible but non-optimal strategies for browsing may also occur (Hammond, 1993). Kinzie (1990) found that students with lower ability or less prior knowledge would need more instructional support, therefore providing learner control is not always desirable. Studies have shown that students lack control strategies for making decisions about instruction; and lack self-regulated constructive learning strategies when using the hypertext system for learning. For a discussion of the psychological theories for learning, chapter 3 provides an overview of competing educational pedagogues which discuss the issue of student control in learning for different teaching styles.

5.8.2 Control in Guided Discovery

An example of a novel approach to using guided discovery as part of larger system is in decision support. The singular goal in a Discovery Learning Decision Support System (DL-DSS) is to provide the user with the capability to explore the complete range of scenarios which may be encountered in a particular domain, considering alternative responses during the decision-making process. Therefore a DL-DSS has to be designed for a variety of potential explorations that can be guided to a varying degree by either the user or the system depending on the problem being studied (Marakas, 1995).

This type of domain exploration is the main impetus of having a DL-DSS in the first place. The user should manipulate and arrange variables to perform various experiments. In this case, an issue which needs to be addressed is which variables the user should be allowed to manipulate and which variables the system should control. Guidance can help the user to gain another perspective into the problem space and should also serve to encourage discovery behaviour. In terms of various discovery tools, another issue is how these should be sequenced or made available to the user. The strong theme that appears throughout the discovery learning approach is that the user should be allowed total freedom in sequencing and manipulating the tools and exploration. This is often the issue when building potential guided discovery environments in education.
However Glaser (1966) points out that users low in ability or motivation may require more explicit guidance if they are to take advantage of the discovery learning environment. Therefore Glaser is a proponent of the “mastery” approach where the user has little control of the sequencing of decision aids and exploratory tools. It has been suggested that the most suitable approach is located between the two extremes. Research from general hypertext approaches suggest that the issue of giving the learner control is problematic (McKnight, Dillon and Richardson, 1991; Kinzie, 1990)

A structured guidance approach could be included in the system that would allow users freedom of choice until it appears that they are not making progress toward a desirable goal. The user could then invoke a system facility that would provide more structure and possibly suggest approaches to the domain exploration until the user feels more confident (Marakas, 1995). This approach for guidance has been advocated for other types of systems such as those using simulations (Shute and Glaser, 1990) and hypertext-based learning environments.

5.9 The Issue of Concepts and Schemata

The definition of ‘concept’ has been seen as a vague term with many different definitions and uses. It has been used interchangeably with ‘category’ or ‘word’. In developmental psychology it has been used to mean competency or the ability for carrying out specific tasks (Sprinthall and Sprinthall, 1990; Cohen, 1989). In this thesis concept is defined as a mental representation of a category (Howard, 1987). Others such as Novak and Gowin (1984) define concept as a regularity in events or objects designated by some label. A category is a class that stimuli are placed in on the basis of some similarities between them.

In placing stimuli together by using a concept, doing so provides the advantage of new stimuli being treated as class members rather than being considered unique. Therefore past experience in dealing with category members can be used to suggest how to act with new ones. Members of a class concept are referred to as exemplars or instances. A concept allows the learner to assign the stimuli in or out of the category
and, if able to carry out this task of assignment, is a sign that the learner has understood a concept.

There are many theoretical approaches for explaining how concepts are acquired and how they should be taught. Questions centre on how best to present a concept so that the learner can readily understand it, how to ensure that the learner's concepts correspond to the teachers, and how to ensure that concepts are related to others so that they can evolve with experience and both be applicable to problem-solving and memorisable. The views concerning these questions, specifically how to teach concepts, can be classified into different groups (Howard, 1987): the classical, prototypical and exemplar approaches.

The classical approach lists the features of a concept that defines what makes it unique from other concepts, but which is shared by all the concept's instances. To acquire concepts, there is a process of abstracting the common features from instances and then applying these features in order to categorise a concept. The prototypical approach proposes that a category is not represented by a set of defining features. Instead concepts are represented by some measure of central tendency of a category's instances, and some notion of their variation. Acquisition involves learning the feature of a typical instance that is at the category's centre (the prototype is the idealisation of the concept). The exemplar view is in direct contrast to the previous two views. The learner remembers one or more examples of the category without abstracting anything from them. Analogical reasoning is used to achieve categorisation instead. The learner begins the process by looking for an analogy, ascertaining the similarity between the given stimulus and the stored exemplars.

There are two cognitive processes which lead to concept learning; discrimination and generalisation. Discrimination is when the learner is able to differentiate between two stimuli and is able to respond differently to them. Generalisation is when the learner is able to respond in a similar way to two or more discriminably different stimuli. The same stimulus is rarely repeated in exactly the same way so it is necessary for the learner to draw on past experience to be able to generalise. The use of both skills, of stimulus discrimination and generalisation, allows the learner to learn new stimuli; to
determine relevant features and irrelevant ones, and to generalise among stimuli to form certain concepts.

In terms of hypertext structure, each concept can be represented as a hypertext node. In this case a complete definition of the concept needs to be defined containing a concept name, a list of critical attributes and its relation to other concepts. The attributes are essential because they form the information which the learner can use to recognise other concepts which belong to the same class.

The hypertext nodes can be organised to form a schema. A schema is a mental representation of a set of related categories, a particular aspect of the world, with slots that are related to each other. These slots contain information about the stimuli, in order to create an instantiation of the schema. Schemata are used in perception, comprehension, memory and especially in learning. Failure to comprehend may result from not knowing which schema to select, selecting the wrong one or one different from that intended. It is suggested that schemata are present as structural entities in human memory and thought, being able to promote learning and retention.

Because hypertext can resemble a schema, it is suggested that it will partly allow the learner to impose a personal structure onto the material. Therefore the notion of a schema is that it is like an organising device able to allow learners to place some objects (instantiations) in one category and the rest in another. The schema’s slots can be filled by stimuli and also act as a filter, allowing some stimuli to be categorised but not others.

The guided discovery condition in this experiment, portrayed as extra levels of guided hyperdocuments with advice, is designed to instruct the learner in a specific concept or principle and ways that it can be learnt. These are the relevant nodes that the learner should grasp, in terms of the overall schema of that particular lesson. The aim is to focus the learner on the relevant concept and then support the understanding of the concept by illustrating characteristics of that node. This is supported by a cognitive map, which will integrate with the specific advice being received at that discovery step. Therefore support is given both at the node level and at a higher level; developing cognitive strategies for browsing the overall hypertext to determine how
nodes are inter-related. This will lead to the assimilation of new material to form a set of related categories, thus creating a cognitive schemata of the knowledge domain. The next section will examine the theory behind the specific cognitive tool used in this research, concept maps. Chapter 8 examines the design of the concept maps used in the guided discovery and map only condition.

5.9.1 Concept Mapping

A concept map is a schematic device for representing a set of concept meanings embedded in a framework of propositions. These provide an explicit representation of the author's knowledge and focus on the details of other concepts and the relationships between them. Concept maps are intended to represent meaningful relationships between concepts in the form of propositions. Propositions are two or more concept labels linked by words to form a single semantic unit. The simplest concept map would be just two concepts connected by a linking word to form a proposition (figure 9).

![Concept Map Example](image)

**Figure 9: A Concept map for sky and its related concept**

Figure 9 displays the concept that the "sky is blue", forming a simple concept map for a valid proposition about the concepts "sky" and "blue". Because learning is easier if new concepts are subsumed under broader, more inclusive concepts, concept maps are usually hierarchical. With general, inclusive concepts at the top of the map, with progressively specific, less inclusive concepts arranged below them. This idea follows Ausubel's (1968) idea of subsumption, whereby new information is often able to be related to and subsumable under more general, inclusive concepts. At the base of the concept maps it may-be useful to add specific objects, events and examples to illustrate the concept. This can be seen in figure 10 (taken from the electronic logic web domain material).
Figure 10: Concept map for Lesson on Unknown Compounds (from Guided discovery condition)

Concept mapping involves the theory of meaningful learning. Proposed by Ausubel (1968) it is in direct contrast to rote learning. To learn meaningfully the learner must choose to relate new knowledge to relevant concepts and propositions that they already know.

In rote learning new knowledge can be acquired by whole-scale memorisation, and subsequently incorporated into a learner’s knowledge without interacting with what is already present. It is important when designing an Internet hypertext system for learning to distinguish between the types of instructional strategy that is to be used, and the type of learning process in which the student is engaged. Learning can vary from rote learning to being highly meaningful, from reception learning (where
information is provided directly to the learner) to discovery learning (the learner identifies and selects the information to be learned). This has been discussed in chapter 3 on discovery learning. It is suggested in the findings of this research that guided discovery learning will invoke deeper, meaningful learning.

The research into concept mapping has more recently been used to contribute to findings on metaknowledge and metalearning (Novak and Gowin, 1984). Metaknowledge refers to knowledge that is concerned with the very nature of knowledge and knowing, examining the structure of knowledge and the process of knowledge production. Metalearning refers to learning about the nature of learning, or ‘learning about learning’. First described by Ebbinghaus (1913) it was used in the study of memory.

Concept mapping is seen as a tool able to help students learn about metaknowledge and metalearning. Novak and Gowin (1984) view this type of research, using concept mapping to promote meaningful learning, as a direct contrast to other approaches that do not discuss the conceptual nature of knowledge and the processes which learners use to construct knowledge. Metalearning and metaknowledge are interconnected approaches to knowledge that characterise human understanding. Learning about the nature and structure of knowledge helps students to understand how they learn and knowledge about learning offers a greater understanding of how new knowledge is constructed. The research carried out in this thesis can be used to contribute to metaknowledge and, to a greater extent, metalearning. It is suggested that the most successful metalearning strategies are accompanied by information about metaknowledge, hence the need to discuss both in the context of designing a hypertext system for carrying out learning.

The primary function of Concept maps is to make clear to both students and teachers the key ideas which they must focus on for the specific learning task. Another navigational support function is as an advanced organiser for aiding students to relate new knowledge to existing knowledge. It can provide a ‘visual roadmap’ (Novak and Gowin, 1984) showing some of the pathways that the learner may take to connect meanings of concepts to propositions. After the learning task has been completed, concept maps can provide a schematic summary of what has been learnt. It is these
strengths that have made concept maps so attractive as a device that can possibly enhance learning in the guided discovery approach advocated in this thesis. It is proposed that the concept map will aid the learner in understanding the material at a conceptual level, incorporating new information into existing knowledge structures. That it will also help in the recall of information and will guide learners by showing how the nodes through the hypertext material are connected, hence providing information about the structure of the hyperdocuments. As Jacobs (1992) notes:

"The principal attraction of hypermedia is that it lends itself to naturally non-sequential educational approaches, since it encourages the free association characteristics of human thought".

The use of a concept map is a hypothesis of this experiment. The basic argument is that the guided discovery will be enhanced by the addition of this cognitive tool, and that just adding a concept mapping tool to conventional hypertext will not promote as effective a meaningful learning experience. Providing an expert conceptual model of the domain will focus the learner's attention on particular parts of the information; forcing them to examine the relationship between the concepts when working through the hypertext material. Navigational support will help to alleviate the cognitive overload problem caused by not knowing where the learner is, where the learner has come from and where to go next, again assisting the learner in focusing on the knowledge domain (Conklin, 1987). The next section will examine how these maps have been used in hypertext systems and the learning outcomes that have resulted.

5.9.2 Concept Mapping and Educational Hypertext systems

Concept mapping is a technique for externalising concepts and propositions. Concept maps are usually prepared by the teacher with specific contents to aid learning and instruction. Spatial maps, similar to concept maps, have been used to support searching and browsing. These will be discussed to illustrate if they can aid navigation; to determine whether one of the functions of using concept map - that of relieving cognitive overload through reducing disorientation - is evidenced by this area of research. Using concept maps for memorisation and as advanced organisers
will also be examined; with discussions of the issue of authoring and generation of concept maps for use in learning.

Research into navigation has suggested that learners can get lost in hyperspace and that disorientation can occur (Nielsen, 1990). It is suggested that maps could be used in hypertext systems to alleviate this problem and that it should:

"include an explicit representation of the network structure and at its user interface" (Halasz, 1988).

The empirical evidence regarding the effectiveness of maps as navigational aids in hypertext is less clear cut. Others have argued that the inclusion of a non-interactive map could lead to an increased efficiency in navigational behaviour (Monk et al., 1988).

Simpson and McKnight (1990) found that subjects who were given access to a graphical contents list, that depicted the relationships between various parts of the text, were more efficient in their use of the hypertext in terms of the accuracy of the route through the document. These were better able to represent the hypertext structure as a cognitive map, rather than subjects who had access to an alphabetical index. Allinson and Hammond (1989) have also shown that the inclusion of a map increased the amount of material reviewed during the browsing phase and decreased the amount of nodes repeatedly opened. These findings indicate that a graphical representation in the form of a map may help users to overcome some of the problems created by disorientation.

By contrast, Stanton, Taylor and Tweedie (1992) found that the inclusion of a map resulted in poor performance in a sentence completion task, less exploration of the material in terms of following secondary links and reported feelings of lower perceptions of control by the user of the system. Learners in a hypermedia environment for learning about fundamental principles of electricity (Wiles and Wright, 1997) reported that they were getting lost in the information. They initially suggested a solution of using a mapping system to inform users where they had been, but found that using a History and Bookmark function was sufficient. Therefore the
benefits of using general maps for navigation remains unclear. Other factors may affect navigation using a map, such as prior knowledge by the user and cognitive style differences (McDonald and Stevenson, 1998).

McDonald and Stevenson (1998) conducted an experiment to determine which tools would help novice users overcome a lack of conceptual support during hypertext navigation. It was suggested that expert users would have fewer navigation problems because of a greater grasp of the conceptual structure of the subject matter. The effects of two navigational tools, a textual contents list and a spatial map, were used to examine navigation performance on non-linear hypertext. The results were that both knowledgeable and non-knowledgeable subjects benefited from the use of navigational tools, but that the spatial map was more beneficial than a contents list. Non-knowledgeable subjects would use the map more often, and both types of users used it when browsing. In terms of learning, it was argued that the spatial map reflected the conceptual structure of the document allowing non-knowledgeable subjects to eliminate differences in test scores and material used, in relation to knowledgeable subjects. Therefore spatial maps can possibly promote the development of conceptual knowledge as well as alleviate the disorientation problem. But others have suggested that a map may be detrimental to learning as cognitive development will only take place if users build their own model of how ideas are interlinked rather than being provided with one by the author.

This pedagogical issue relates to whether the students would benefit from viewing the teacher’s concept map. A constructivist approach (Kommers, Jonassen and Mayes, 1992) would suggest that the students should construct their own views as they progress through the hypertext. But it is argued that if the students are to use hypertext, they are more likely to benefit from seeing a teacher’s more coherent, experienced view of the knowledge domain (Elliot et al., 1995). A second issue focuses on the ability of teachers to externalise and make explicit their own understanding of a subject. Attempting to create concept maps of domain knowledge could help teachers to understand the domain material. This in some ways reflects the finding of Mayes (1993), that the creation of hypertext for use as cognitive tools can benefit the authors of the hypertext courseware more than the students who use it. A
possible solution in the creation of concept maps is for the system to generate them as the learner works through the material.

Auto-generation of maps allows the system to generate maps of the information space as the learner searches and browses. The user can then read the document, generate a query from available concepts and the conceptual map will be re-drawn. (Rada, 1995). This may be a worthwhile tool for very large information spaces or database systems. It is suggested that there is no need for this facility in the system built for this experiment, as the hypertext space is well structured, it is less fluid than one for use in an open corpus of material which is often transitory (Elliot et al., 1995), and there is only a need to show localised, smaller maps at any one time. Showing large, complex maps will only add to the cognitive load of the users as they view concepts that may not be necessary at that current stage of the learning process. For a discussion of methods to generate maps for very large information spaces, Zizi and Beaudouin-Lafon (1995) provide a comprehensive discussion of interactive, dynamically generated maps; and Chen (1998) examines issues with the spatial layout of maps. It is suggested in this thesis that a tutor-prepared concept map representing particular concepts and relationships is sufficient to support learning.

In terms of supporting memorisation, Kozma (1992) suggests that concept maps are more advantageous than normal text-based notes in aiding memory. By relieving the burden on short-term memory, using concept maps can allow students to carry out other activities to engage at a deeper level with the concepts. Because the relationships between the links are made more explicit, the knowledge is communicated more easily. As they contain externalised expressions of propositions concept maps are effective tools in helping overcome misconceptions by displaying a visible linkage between two or more concepts showing a clear idea of why these concepts are related (Novak and Gowin, 1984).

Using maps to function as advanced organisers will allow students to slot new material into an existing conceptual framework or to create a new framework (Ausubel, 1968). In terms of the purpose of using concept maps in this experiment, they will be used to support browsing as the learner moves from node to node. Concept maps show, at the node level, concepts that have already been encountered
and also new material that has yet to be accessed. Therefore there is a bridging between concepts (which are in the form of hypertext nodes), to cognitively support the learner through the navigation process. This is done by displaying the relationship between the concepts that need to be learnt.

Research into the effectiveness of concept maps for hypertext remain open to investigation. There are qualms over the use of spatial maps. Some researchers have suggested that the use of a physical metaphor to describe hypertext, that of 'electronic space' which the user has to navigate through, is flawed; that there is no substantive proof to support the notion that users conceive of hyperdocuments spatially (Stanton and Barber, 1994). Disorientation can be partly explained as a by-product of bad interface design because it is unclear to the users what actions they can perform, and is not a characteristic of the actual hypertext. In this respect Stanton and Barber argue that spatial maps detract from the cause of disorientation, as they are used to relieve symptoms rather than the actual cause of the disorientation.

In this thesis, it is suggested that the incorporation of a conceptual map will help in overcoming problems of disorientation in order to focus on learning; and that it will also support the cognitive processes in understanding the concepts with the relationships that exist between them. It is also suggested that the concept map will add to the effectiveness of the guided discovery system that the map only condition could not: the essential ingredient being system guidance when using the map in the guided discovery condition.
5.10 Instructional Theory and Design

Instructional design examines: different types of instruction, when to apply them and how they affect the user interaction. Determining a suitable type of instruction is dependent on what the courseware designer wants to achieve in terms of user knowledge and skills. Currently there are no established models that can be applied to the design of educational hyperdocuments for the WWW.

Part of this lack of guidelines is because conventional hypertext is different from traditional instructional design models which tend to stress the predictability of learner actions. This reflects the behaviouristic approach found in drill-and-practice systems that require the learner to continually follow a specific path of learning.

Due to the ability of the user to browse without restriction in a hypertext system, the behaviour of the learner is less predictable. CAI systems may also have shallow representations of instructional goals, and an expert performance element with which to compare learner progression. But educational hypertext systems often lack an explicit curriculum based on an explicit theory of instruction and learning.

There are several theoretical assumptions about the potential of hypertext for learning. This stems from the ability of hypertext to represent subject matter in a non-linear fashion, to enable flexible information access and self-regulated learning and to also represent a subject matter from different views, using different symbol systems. There is also the possibility of being able to even revolutionise learning using hypertext-based technologies, to overcome the deficiencies encountered in the traditional reading comprehension and information processing approach of teaching and learning (Jonassen, 1986; Landow, 1990).

Hypertext as a system for promoting learning was not initially recognised until the realisation that non-hierarchical information access could provide a reactive learning environment. Because of less emphasis on the power of the user model, exploratory or discovery learning could provide the promise of active learning. In supporting the idea of learner control, computers could provide environments whereby discovery
learning could occur. Learning by browsing emphasised the possibility of this paradigm and browsing was in itself seen as a natural mode of navigating through the information space.

This paradigm emphasised the constructivist approach (Mayes, 1993; Wiles and Wright, 1997) whereby an essential requirement of learning would be to "think active" (McKendree, Reader and Hammond, 1995). Therefore some systems have offered complete learner control, with interactivity being given by direct manipulation interfaces to large multimedia databases containing teaching material. The value of this approach in hypertext has been questioned, nevertheless.

As Hammond (1992) has pointed out, it is not guaranteed that the learner will select the information to see next in a way that will lead to effective learning. Therefore as Mayes (1993) argues:

"unguided choice may be as inefficient as no choice".

In terms of the effectiveness of discovery learning through browsing; unless the browsing is directed by answering specific goals, or problem-solving tasks then it may only support a shallow experience. Difficulties related to browsing and disorientation for general hypertext are also applicable to using hypertext for learning. These may echo the "art house" problem; whereby the learner has seen several paintings (in this case hyperdocuments) but is unable to remember any detail or understand what has been seen. In hypertext systems, high cognitive demand leads to similar problems of remembering and summarising information that have been read, with a subsequent lack of recall for details of any particular parts (Kim and Hirtle, 1995). Symptoms are short reading times indicating only cursory examination of node contents and restrictive search paths.

5.10.1 Instructional Design, Interventionist Strategies and Learner Control

Theorists such as Merrill (1980) hypothesise that learning will be improved if the learner is given control over the instructional experience so that it will be suited to
specific needs and goals. But although learner control is said to encourage discovery, limited research has been conducted to determine the best instructional strategies to do so.

The components of learner control and self-regulation of learning are examined by Kinzie (1990). Questions that are examined are whether, if the learner is given learner control: (1) the learner will be able to manage their own learning in an effective and productive way, (2) will the learner be able to make good choices and (3) will this be complimented by an increased interest in wanting to explore the hypertext domain. Self-regulation of learning implies that there will be a high level of cognitive engagement such as: (1) actively receiving and selecting information, (2) making connections with existing knowledge, (3) organising the approach to the learning task and (4) continuously monitoring learning.

It is suggested that particular types of instruction can encourage the use of these self-regulative skills and can promote increased perception of personal control, relevance and curiosity. The rationale for giving learner control was the proposition that each individual will know what is the best way to explore and will act on that knowledge (Merrill, 1980).

Motivation is another important component in the design and utilisation of interactive instructional systems (this has previously been discussed in the context of discovery learning, chapter 3). The concepts of intrinsic motivation (concentration on the way to solve a problem) and continuing motivation (the student's willingness to learn) provide a contribution to instructional research and design. Educational theory suggests a number of instructional components are directly linked to these types of motivational outcomes. These components are the promise of competence, the perception of relevance, the perception of personal control and the stimulation of curiosity (Kinzie, 1990). Individuals who perceive that their behaviour stems from their own choices will exhibit more motivation than those who feel that their actions are dictated by external forces. This perception of control, or internal locus of control, encourages the growth of skills for self-directed learning. Self-regulation of learning is seen as being of paramount educational importance. Therefore when determining the requirements in effective design of interactive instruction, there
should be consideration of learner control, self-regulation and continuing motivation. Environments should be built that allow the learner to exercise control.

In terms of instructional design theories there has also been a shift from behaviourist to cognitive design, which could be argued as resembling the shift from traditional CAI to hypertext. This had previously been overlooked when considering learner control. Clark (1984) describes instruction in a behaviourist design to be highly directed, with shorter steps, more practice and feedback and nearly identical elements both in instruction and post-testing. This type of instruction was more commonly delivered in the classroom. In contrast, instruction based on cognitive design allows the student control over direction and monitoring of the learning process. The instruction tends to be at a higher level of difficulty and is presented in larger chunks.

In this type of learner-controlled experience, the outcome is long-range achievement and continuing motivation to learn. By giving instructional control to the learner, another advantage is that the learning process become active (Landow, 1990, Jonassen, 1986). In terms of measuring achievement, learner control in cognitively oriented instruction may promote the construction of large-scale knowledge structures (as well as promoting self-management of learning and continuing motivation) but there may be no measured benefit if the test used is based on behaviourist design.

It remains inconclusive about the effect of allowing a high degree of learner control for all domains and all types of learners. Highly structured, behaviourally-oriented instruction may preclude the growth of higher levels of cognitive engagement for some students. Those who have previously only been given highly structured instruction may be incapable of managing their instruction when given the opportunity.

There are some suggestions that structuring hypertext by imposing any type of semantic structure will detrimentally affect the learner's requirements (Duchastel, 1990). The opinion in this thesis is that the user can be left to explore, according to preferences and needs, but that a form of system control is necessary (La Passardiere and Dufresne, 1992). The research in this thesis suggests that structuring the navigational process by providing advice about navigational paths will reduce cognitive overload, the use of a cognitive map will reduce disorientation, and different
levels of guidance will promote a higher level of cognitive engagement (Kinzie, 1990) resulting in meaningful learning. The selection and sequencing of the material will be a mixture of learner and system control with an investigation of whether this encourages motivation to explore the domain.

5.11 Learning Styles

Learning Styles was measured to determine if this factor had any influence on learning outcome and user satisfaction related to the different experimental conditions (guided discovery-based, concept map and unguided hypertext). It has been suggested that not all learners will be equally suited to learning with hypertext because it may not provide the stimulus required. Studying the relationship between learning style and hypertext will provide information about how hyperdocuments can be used to enhance and support learning preferences, determining factors such as locus of control and system feedback.

Previous studies have shown learning style to alter learning in a classroom scenario, and CAI systems and also in educational hypertext (De Diana and van der Heiden, 1994). A discussion follows with an assessment of learning styles research combined with a description of the measurement tool for assessing learning styles used in this project. The final section outlines specific hypertext systems that have been built to take account of learners preferred styles of learning. The findings from both classroom practice and educational hypertext environments will be used to predict whether users with different learning styles will experience differences when using the different conditions.

5.11.1 Models of Learning Styles

The term learning styles refers to individual characteristic and preferred ways of gathering, interpreting, organising and thinking about information. An example of this is that some students prefer to work independently while others prefer group
work. Others prefer to acquire information through reading while others prefer to incorporate active manipulation into the learning task. Various models of learning styles have been put forward, such as Wilkin's field independance and field sensitivity model.

Wilkin's model of learning styles focuses on personality, and divides learners into two broad categories: field-independent viewers (those not distracted by global complexities), and field sensitive viewers (those more easily distracted by complexity). But the model proposed by Kolb (1984) has received greater usage in assessing learning styles (Davis, 1993).

Kolb (1984) proposed that when adults undertake to learn something for themselves there is a natural learning cycle which follows four stages. The starting point is concrete experience, followed by observations and reflections on that experience. The third step involves using concrete concepts and generalisations, often in the form of diagrammatic models to make sense of the reflections, which leads onto the testing of the implications derived from the models or theories in new situations. Linking the outcomes of the experimental phase back to the original concrete experience completes the cycle of learning.

The cycle is developmental, in that it can resemble a spiral rather than a circle, with the result of a complete cycle being at a higher level than at its' point of origin (Entwistle, 1992). This model has been useful in suggesting alternative teaching methods that may encourage students to reflect on their own experience, or to provide real life experiences from which to develop this learning cycle. Kolb's Learning Style Inventory, although used in many studies, was seen as too theoretical in its approach. Instead, this research decided to use Honey and Mumford's Learning Style Questionnaire (1982).

This variant of the model by Kolb provided two advantages. Firstly Honey and Mumford deliberately built their views of learning styles, and the questionnaire, around recognisable statements of behaviour. This makes it easier to administer and measure subjects' learning styles without losing validity. Secondly the main aim of their work was to produce a framework and tools that could give detailed practical
guidance to those who are trying to develop specific learning styles and to teachers. Descriptions of learning styles are generally more detailed and are modified from Kolb’s equivalents. Honey and Mumford’s Learning Style will be examined in more detail to provide descriptions of characteristics that may influence learning in an educational hypertext environment.

5.11.2 Honey and Mumford’s Learning Style Questionnaire

Honey and Mumford (1982) have concentrated on what learners do, suggesting that after measurement of learning styles there can be certain types of learning activities that are congruent or incongruent with the dominant learning style of the individual. Learning is described as a continuous cycle whereby learners have an experience, review the experience, derive conclusions from this experience and then plan the next step. Figure 11 illustrates the stages of the learning cycle, with learners able to enter at any of the stages and to move forward and backward through the stages.

![Figure 11: Cycle of Learning and Learning Styles (Honey and Mumford, 1982)](image)

Because some individuals have a preferred style of learning style, learning activities can take advantage of these preferences by providing certain tasks and material. A mismatch could occur if the learning activity does not fit the learners’ particular preferences. Kolb uses different terminology to describe the stages of the cycle and
the names of the learning styles; but they are similar to Honey and Mumford's descriptions.

Learners will tend to choose activities that suit their preferred learning styles over other stages in the learning cycle. The learning styles can be determined by self-administration of the Learning Style Questionnaire (LSQ). This consists of 40 items, which the user can ‘tick’ or ‘cross’, with the subsequent score plotted on a scoring schema to determine individual dominant learning styles. Four styles can be derived: activist, reflector, theorist and pragmatist learning styles. The characteristics of these preferred learning styles will now be discussed.

**Activists**

Activists involve themselves in new experiences without anxiety or hesitation. They are content to be dominated by immediate experiences and enjoy the present rather than the past. They are open-minded, not sceptical, with a tendency to be enthusiastic about most new experiences. Their philosophy is to try anything at least once, tending to act first and considering the consequences afterwards. Their lifestyle is one of constant activity, and as soon as one task is finished they look for another. Problems are tackled by brainstorming with a need to seek new experiences; being bored by tasks that require implementation and longer-term consolidation. They are gregarious people who are constantly involving themselves with others.

**Reflectors**

Reflectors prefer to stand back to ponder experiences and observe them from many different perspectives. They collect data, both personally and from others, and prefer to consider it thoroughly before reaching a conclusion. This thoroughness in the collection and subsequent analysis of data about experiences and events is what is considered as important, so they tend to postpone reaching definitive conclusions for as long as possible. Their approach is to be cautious, taking a quieter role in meetings and discussions. They listen to the opinions of others before joining in on a
discussion. When they do decide to act, it is often as part of a wider picture; which includes a consolidation of past as well as present observations.

Theorists

Theorists adapt and integrate observations into complex but logically sound theories. They tackle problems in a vertical, step-by-step, logical manner. Assimilating disparate facts into a set of coherent theories. They tend to be perfectionists, only stopping if the task is tidy and completed in a rational manner. They are enthusiastic about investigating basic assumptions, theories, models and systems. Their approach is one based on rationality and logic. The questions that they ask are often queries about how certain factors are interconnected or the basic assumptions that are present. A logical approach is the favoured option, and their preference is to maximise certainty. Theorists feel less positive about using subjective judgement, lateral thinking or issues that require personal speculation.

Pragmatists

Pragmatists are motivated to try out new ideas, theories and techniques to see if they work in practice. They positively search for new ideas and will find the opportunity to experiment with applications. They will come back from lectures and courses with the wish to try out new ideas, and to apply what they have learnt. The aim is to test ideas quickly and with confidence. They tend to be impatient with open-ended discussion and inconclusive results. Problems and opportunities are seen as challenges.

Each preferred learning style is present in a specific part of the learning cycle. Those with activist preferences want new experiences, problems and opportunities from which to learn. Others with reflector experiences want tasks that allow reviewing. Theorists have less difficulty reaching conclusions and pragmatists prefer to use extensive planning before action. The learning style questionnaire modified for use in
this experiment (explained in section 9.7.5) consisted of 38 items and is included, with the scoring, in appendix A. Details of the administration of the Learning Style Questionnaire are in chapter 8, and pilot results are given in chapter 9.

5.11.3 Learning Styles and Preferences in Educational Research

An understanding of learning styles and orientations may enhance teaching effectiveness; with the desired result being that students may be more satisfied and more productive if they are studying with methods compatible with their styles (Davis, 1993). But caution should be taken when making use of information about learning styles. Research on cognition suggests that it may be more relevant to focus on the cognitive processes students actually use when trying to learn, remember and understand course material rather than just personality or style variables. Also it has been shown that, even though learning styles are measurable, they may not remain constant over time.

Research from studies in higher education suggests that learning styles change over time according to exposure to specific learning activities. Nulty and Barrett (1996) surveyed 673 students in three Australian universities and found that students in the first year of their study adopted learning styles that were similar to each other irrespective of their main subject. However at the end of their studies their learning styles tended to change to reflect the discipline which had formed the primary focus of their studies.

They also found that learning behaviour was influenced by environmental demands and short-term objectives. So if for example the task is to cram for exams, then they may adopt a learning style which will allow them to achieve this. So the learning styles that students adopt may be a result of a gradual process of adaptation to the learning demands placed on them and the rewards systems which they experience. Both demands and rewards are likely to vary in academic disciplines. This flexibility in learning styles was replicated in the work of Sutherland (1995).
Therefore the choice of behaviour depends on a balance between many other factors apart from the students’ own preferences. Nulty and Barrett (1996) argue that preferred learning style is not an absolute, but rather a tendency. The principle is that students tend to favour some learning behaviour over others; even though they may at times adopt any of a repertoire of other learning styles. Therefore selecting a particular behaviour is dependent on the learner’s abilities, environment and learning history. Kolb also found this, demonstrating a link between learning styles of American business managers and the undergraduate degrees that they had previously undertaken.

The focus was different in Sutherland’s study (1995), instead investigating adult learning styles with a sample of 58 tutors and teachers in the United Kingdom. When formal assessment such as exams or assessed coursework were given, the majority would take a strategic approach to learning. If they were producing non-assessed work than they would adopt a deep approach such as playing around with ideas for their own sake. This ability to switch learning styles may appear in the guided discovery condition, but it is suggested in this thesis that guided discovery will not be detrimental to learning preferences and styles in that those using the guided discovery condition will be as satisfied using this condition as they would using any of the other conditions. It was also found in Nulty and Barrett’s (1996) results that students who adopted learning styles matching their chosen discipline reported more positive outcomes.

Educational psychology research suggests that learning styles affect performance and satisfaction. But learning styles are not absolute and can change. A learner may be capable of adopting learning strategies to suit the requirements of particular tasks with other factors also influencing learning styles such as the environment and past experience.

In this thesis, research is undertaken to assess whether hypertext systems offering different feedback and navigational freedom can support learning styles. Honey and Mumford (1982) provide a method for determining the learning style. The conclusion of Nulty and Barrett’s study was that teachers might need to adopt behaviours that are able to accommodate the nature of student’s learning styles. The guided discovery
approach used in this experiment may be able to accommodate certain learning styles rather than conventional, non-guided hypertext. Such as Theorist and Reflector learning styles because these types of learners prefer for example a full discussion of the principle or theory that discovery steps give to the learner. What can be concluded is that particular activities are more suitable for learning preferences and that when these two factors match, the result is that the learner experiences a more positive outcome in learning both in terms of knowledge gain and satisfaction. It is suggested that a guided discovery component will be no more detrimental than conventional hypertext (unguided condition) for learning, and that it will not unnecessarily restrict user freedom or cognitive engagement in the learning process.

5.11.4 Implications of Learning Styles for Educational Hypertext

The results from educational studies provide support for the proposition that learning styles have an affect on learning outcome and hypertext. According to learning styles research, learners will not approach the domain in the same manner. As Davis (1993) has shown, students will be more satisfied and more productive if they study with methods compatible with their styles. Therefore hypertext authors need to take into account learning styles when designing educational hypertext. This is difficult as learning styles can change over time (Nulty and Barrett, 1996; Sutherland, 1995) and Honey and Mumford’s categorisations may not be suitable for all permutations of learning.

De Diana and van der Heiden (1994) provide evidence that learning style does have an effect on learning in a hypertext environment. They argued that it was essential to consider individual modes of learning, when designing a hypertext-like learning environment. They created an electronic study book, a combination of traditional book concepts but with the advantages of an electronic hypertext medium. An advantage was that the system could provide additional cognitive support facilities such as information selection, evaluation, processing and linking.

In terms of individual differences, learning styles lead to different exploratory strategies, hence it is desirable for hypertext environments to provide preferred learning tasks. In traditional educational settings learners can carry out certain
activities such as annotate, interact, add comments or seek pictorial information. It is these kinds of learner's actions that can be further supported by a computerised environment able to adapt feedback accordingly (De Diana and van der Heiden, 1994).

With learning strategies those afraid of failure will most likely adopt a surface-oriented style of learning, memorising pieces of information in order to recall the information for a test. Others who perceive courses as a means of developing a better understanding will adopt a deeper learning style using strategies to explore new information in relation to past knowledge and make inferences about the material. Deep learners will make use of a concept-oriented strategy by creating a hierarchical network in which new information is organised, categorised and examined for flaws. Therefore an optimal environment for learning will be one that supports learners in using various types of strategy which can promote versatile metacognitive learning skills.

A hypertext system able to support: rote learning, operation learning, comprehension learning, and combinations perceived as necessary to achieve the highest grades, remains the desired goal. To be able to adapt to a learner's strategy there should be different representations of information. This could be more repetition of main concepts or ideas if a rote learning strategy is required. For comprehension it maybe to present connections, links or graphical representations between the information.

If the learner is given control of the processing of the material then it could be assumed that the student would impose a preferred learning style on to the way that this was carried out. Hypertext provides this learner freedom. De Diana and van der Heiden (1994) suggested that the system should have certain settings that could support different learning styles. This could be in the form of a tutoring component to control the sequencing of the material, with functions such as record keeping of the learner's path and appropriate feedback.

Other research has questioned the impact of learning style on hypertext navigation in a learning environment. Reed et al. (1995) used the Kolb Learning Style Inventory to assess learning style on 18 students using a hypercard-based program in humanities.
It was found that learning style did enhance learning. Instead factors such as previous computer experience were more influential in determining exploration of the material in a linear or non-linear manner. Learning style did not seem to encourage different types of exploratory behaviour or affect learning. The results could be criticised for being derived from a small student sample and that the given tasks were primarily rote learning. Hence the learners temporarily shifted their learning style to suit the needs of the task set. This serves to illustrate the argument that the effects of learning styles on educational hypertext remain open to question.

Overall the research literature provides some ideas about the structure of a hypertext environment if it is to promote learning when taking into account the factor of learning styles. The environment should: (1) encourage a high degree of learner control, (2) the information should be presented in many forms, and (3) the tasks set should suit as wide a range of learning styles as possible. In this thesis it is suggested that the majority of learners would not be adversely affected by the guidance structure in the system and that the conceptual map will be an additional and beneficial tool for cognitively structuring learning during the exploratory process.

5.12 Hypertext and Semantic Memory Models

Structuring hypertext for effective learning is based on structures of learning, or cognitive models, within the learner. Hypertext can be seen as representing semantic models of memory within the learner. Learning is regarded as the reorganisation of knowledge structures into semantic memory.

It has been suggested that hypertext structures reflect a model of learning based on schemas (Jonassen, 1992). In schema theory, learning is the accumulation and organisation of knowledge structures. These knowledge structures are a representation of the organisation of ideas in our semantic memory. Each knowledge structure exists as an object, idea or event as well as a set of attributes linking it to other knowledge structures. Knowledge exists in semantic memory formulated as a network of interrelated concepts.
As the learner gains new structures and links, information is added to existing structures (also known as accretion), or existing structures are altered through a process of restructuring. Restructuring also involves grouping knowledge structures into procedures, or coarser-grained schemas. Therefore these inter-related series of concepts are called semantic networks. Merrill et al. (1990) suggests that the provision of knowledge-based tools will help in the organisation of this knowledge.

The addition of a semantic networking tool to a hypertext system will provide the learner with a tool for integrating knowledge in a personalised form, linking new knowledge to old. Nodes in the semantic network resemble hypertext nodes and the links in the semantic network represent those of hypertext links. This semantic map could serve as a graphical browser that could also resemble the author's knowledge of that domain. It is seen as beneficial for the learner to see the author's version of a semantic map of the domain because the teacher's perspective will be more coherent and less likely to have been a view that was created haphazardly (Elliot et al., 1995). Cognitive maps are also commonly used throughout the browsing process, especially for inexperienced learners (McDonald and Stevenson, 1998). Therefore these cognitive tools should alleviate the "lost in hyperspace" problem (Conklin, 1987) but also aid in understanding the concepts and principles contained in the domain material.

5.13 Discussion

Although systems for learning using hypertext have been built and tested, the establishment of the effectiveness of hypertext is still unresolved. Criticisms have been levelled at the supposition that hypertext can promote higher levels of cognitive engagement and the development of metacognitive skills. A common criticism concerning learning is that a hypertext structure is too simplistic and could not possibly capture the complexity of human semantic memory. Not enough is known from cognitive and educational psychology to provide input into the design of hypertext for instructional strategies. Assumptions have been made which have not
been investigated into components that would make up such a system, if it was to carry out active instructional guidance for learners (Elsom-Cook, 1990).

Others have strongly suggested that hypertext has received positive praise in computer-based learning which is often misdirected and flawed by too many assumptions. McKendree, Reader and Hammond (1995) argue that assumptions such as hypertext being like the brain, and resembling constructs in the mind, have led to the premises that such structural similarity automatically leads to educational effectiveness. They are not claiming that hypertext is ineffective for learning, but that assumptions have been made which remain unproven. Hypertext for learning can continue to benefit from psychology but there is a need for further research into how to promote learning. The data collected for the effectiveness of educational hypertext has continued to be criticised for lacking both in experimental rigidity and also in classroom practice.

Lack of scientifically collected data (Kinzie, 1990) has cast questions over the reliability and validity of the conclusions that have been reached; and a slow adoption of CAI generally has meant that widespread application of hypertext learning systems have been slow (Entwistle, 1992, Elliot et al., 1995). When attempting to introduce hypertext systems into the classroom, there have been examples of successful uses of the systems to compliment learning. But again the lack of control of variables has meant that it is unclear what effect the hypertext system has for learning and what has occurred due to changes in the teacher's strategy when faced with this new variable. With the majority of the results of classroom studies also coming from qualitative methods such as participant observation, there is a lack of quantitative data needed for generalising across other subject areas and educational situations.

The hypertext systems that have been developed continue to require the learner to have a strong understanding of location in the hyperspace. The advantage of the freedom to browse can be counterbalanced by disorientation, cognitive overload and a lack of specific goals to direct the learning. It is also unclear how individual differences affect learning success with hypertext. Those with no previous experience of such a structure may not know how to carry out learner-led exploration; others may need a structured approach at the beginning before they can begin to develop deeper
levels of understanding. In terms of the locus of control and instructional design, individual differences in intelligence (Altamura and Roselli, 1995) and previous experience can counter the structure of hypertext. Therefore there seems to be a compromise between the freedom to explore and the overt control exerted by the system, a compromise which remains unclear. System intervention requires further research to overcome the deterministic, over-structured approach found in earlier CAI systems (Romiszowski, 1988).

When offering the option of control to the learner it has been found that a majority of users are quite content to follow a linear, pre-defined path through the material. This suggests that the task of the author to structure the material in a cognitively efficient manner is a crucial part of designing a successful hypertext learning system.

In terms of interactivity during the learning process, the suggestion is that students tend to be passive learners with hypertext being a relatively passive medium (Edwards, Powell and Palmer-Brown, 1995). When choosing an exploratory path, it is unclear how active carrying out this action is. Designing a system that allows interaction, providing feedback concerning progression, supporting the re-organisation of material to make it more understandable are all possible ways to embed interactivity into the learning environment.

The proposal of this thesis is that: (a) gains in knowledge will result from providing guidance when the learner has missed information due to inadequate sequencing and progression through the material, (b) when experiencing difficulty in understanding concepts in the domain a guided discovery approach will allow connections to be made with existing knowledge; hence providing support for the interconnected action of navigation and mental processing. The aim is to find a compromise between complete freedom to explore, and self-perception of user control; by using non-disruptive, interventionist support for cognitive processing.

There remain no established guidelines for designing hypertext for learning and a lack of agreement on an instructional design theory for hypertext, although hypertext seems to support most cognitive theories of learning. Students report that they enjoyed using hypertext systems such as Intermedia (Meyrowitz, 1986) and
Strathtutor (Kibby and Mayes, 1989) but difficulties exist in isolating why this is. Learning styles are examined to determine their effect on learning using a hypertext environment, as it is regarded as part of a set of individual characteristics employed in learning. Research is needed into individualistic factors that affect learning with hypertext.

Using a guided discovery approach in the design of a WWW hypertext environment will be discussed in chapter 8. If the guided discovery approach is too intrusive and restrictive, by hindering the freedom to explore the information space or if the advice does not help to conceptually grasp the material, then there will be higher dissatisfaction reported by the subjects.

Developments in the merging of AI techniques (derived from ITS) with hypertext environments provide a possible way to overcome some of the criticisms that have been levelled. The research carried out in this thesis examines the design, development and testing of such systems. The embedding of an overt guidance component, coupled with a pedagogical approach to structuring the material can create a system able to support learning. The use of concept maps will help to provide the navigational support identified in the hypertext literature as being needed.
Chapter Six

Issues in Distance Learning and the WWW

6.1 Introduction

The growth of the Internet has been explosive. It can act beyond being just another delivery system and instead create applications which can provide education in a radically new way that previous technologies had not (Eklund, 1995). Some have compared the introduction of the Internet into the educational arena as the most educationally significant teaching tool since the use of chalk in the classroom. Therefore it is predicted that the Internet will be a major factor in how education will be delivered in the future.

A survey of educational resources on the Internet (Edmonds and Pang, 1995) suggested that courses which purported to be tutorials or self-teach modules were no more sophisticated than obtaining the text from the library in a book form. Although this survey was taken before the creation of programming languages such as Java (Gosling and McGilton, 1995) had become significant it suggests that much of the teaching material was static. There was some educational material which used multimedia (Kinzie et al., 1994), but generally the student would follow a set of conventional textual hypertext links.

This linear approach remains suitable for some topics, but is removed from the interactivity and freedom to explore which educational psychologists have cited as necessary for exploratory learning of more conceptually-orientated material (Steinberg, 1988). To provide a guided discovery approach to some of these educational resources would allow guidance, as well as freedom to explore, to be incorporated into the instructional web material.
One of the main paradigms upon which the World-Wide Web (WWW) is based is that of browsing. Documents are linked together in hypertext links; clicking on a link signals the browser to fetch the other document from wherever it is stored. This may be in a different continent and remains mostly transparent to the user. The retrieved document is displayed on the Internet browser so that users can read the information. A major weakness of the browsing paradigm, however, is that users not only get lost in cyberspace but can forget how they managed to initially locate the web page. Another problem is that the Internet is relatively slow. Going from one link to another can take minutes, not to mention the frustration felt when links are often broken because a network or a server is either experiencing difficulty or overloaded with requests (Klark and Manber, 1995).

When designing a system for distance learning, certain factors should be taken into account, which previously were not present in the operation of traditional hypertext systems. A discussion will follow of changes in distance learning with the introduction of the WWW and changes in the types and numbers of learners who may be using WWW educational systems in the future.

The latter part of this section will examine specific resources on the Internet which will influence the way that hypertext-based educational systems can be used, and the predicted way that a guided discovery learning environment will be used in the future. The need for learning environments has partly come from the increasing demand for the provision of distance learning, rather than the use of the Internet technology just because it is available (Debreceny, Ellis and Chua, 1995). There have been many diverse approaches to giving students access to education and these will highlight ways in which the guided discovery environment can be incorporated as part of these other educational technologies.
6.2 Size and Growth of the Internet and the World-Wide Web

The Internet is best viewed as a ‘network of networks’. It is the physical infrastructure which connects computers world-wide and provides the capability of transmitting electronic data between different systems, platforms and languages. This is often organised as a client-server protocol (the Hypertext Transfer Protocol - HTTP) with an Internet programming language (the Hypertext Markup Language - HTML) which allows data to be displayed in the form of a web page.

The World-Wide Web (WWW) is a means of navigating through the Internet, providing a visual display of the data in the form of hypertext documents (Berners-Lee et al., 1994). This is displayed on a viewer, with the most popular being Netscape’s Navigator and Microsoft’s Internet Explorer acting as both a browser and a navigational tool. When the user, or ‘net surfer’, clicks on a hypertext link the browser will automatically ‘jump’ to another document, film, sound bite or application. The ease of use and world-wide access on multiple platforms is why the WWW is so successful. This is also the reason why the WWW provides so much appeal to educators who want to provide learning over a distance and within a certain timescale. There has been a rapid growth in the different ways that the WWW has been used.

In terms of user numbers, estimates vary according to the method of measurement. In 1997 there was estimated to be easily over 7 million host computers on the Internet, with the largest group being 1.74 million .com (commercial) domains and 1.41 million .edu (educational) domains (GVU, 1998). Therefore the Internet is a global phenomenon with 150 countries connected to the Internet. This is further enhanced by the growth in web sites on the Internet, with the web growing by 1758% in 1994 alone and doubling in size every two to three months. Statistics also show that Web traffic now dominates Internet activity in relation to other uses (Hoffman et al, 1995).

The Graphic, Visualization and Usability Center’s WWW User Survey (GVU, 1998) collected over 12,000 responses and provides the largest web-based survey so far on user background and behaviour. The findings suggest that the average age of the
WWW user is thirty three years, predominantly male (with only 31.5% being female) and educated to college or university level, with half of the respondents accessing the web from home and paying for the service. Over 80% accessed the web on a daily basis with the most common activity being browsing at 78.7%, followed by entertainment, work and shopping.

What is suggested by Hoffman et al. (1995) is that these types of users represent the current area of growth but this will change with future web growth coming from a 'downstream segment'. This downstream segment is less gender-skewed, younger (with 70% being under 30 years) and on their way to obtaining qualifications. Although these surveys are not necessarily representative of the 'typical' user it does suggest that web-based educational resources will be used in the future by students and adult learners. Because the number of younger users is expected to rise, this will create a group of users who know how to use the Internet and may accept the idea of learning online instead of using the WWW to browse.

6.3 The Increasing Demand for Distance Learning

The modern use of the term 'distance learning' implies the use of a wide range of interactive technologies to reach learners who would not otherwise receive instruction; because they are separated from the source of instruction by either space or time. The effective use of distance education requires the provision of quality courses and programs that are systematically designed to support more independent learning and to take full advantage of the attributes of mediated instruction.

Distance learning is designed to improve access and provide broader educational opportunities. It is integrated into the community and takes advantage of local resources. There are many trends both in society and in education which support the development of distance learning capabilities. Demographics are changing. Within society there are increasing numbers of non-traditional, lifelong learners who are working adults.
At the same time universities are under pressure to develop the most cost-effective methods for the use of resources (Debreceny, Ellis and Chua, 1995; Whittington and Sclater, 1998). Additionally, developments in telecommunications and instructional technologies have grown exponentially providing opportunities for the development of learning environments that engage students as active learners and problem-solvers. Therefore universities world-wide have had to deliver their programs in a multitude of geographical and environmental settings. To be able to deliver these programs there will be a need to establish design methodologies to carry this out. There is a need to move away from an on-campus model of learning if the universities wish to reduce costs. Recent developments in educational technology, especially the growth of the WWW, can make this feasible.

Rapid changes in educational technology provide the opportunity to change from traditional teacher centred paper-based models to learner centred, electronic based models. But there remains a lack of discussion about how this shift might be achieved. Bates (1994) predicts that in the future, work and learning will be inseparable whereby the university, as will work, be composed of several characteristics: (1) working alone, (2) interacting with the material, (3) working collaboratively with fellow students, and (4) as a student with a supervisor or as a 'mentor' to other colleagues.

Debreceny, Ellis and Chua (1995) chart a move in the use of technology for distance learning and propose a networked learning model. This model integrates on-campus and off-campus delivery. There is the creation of a substantial core of common resources made up of textbooks, printed notes and access to computing resources. The computing environment uses email, WWW and virtual educational environments such as Multi-User Dungeons (see section 6.9.3) to link students with academic staff. The suggestion is that the core component will take advantage of both existing traditional paper-based resources; coupled with newer Internet technologies to provide interaction, feedback, participation, collaboration and idea generation. Therefore the latter is essentially a substitute for traditional face to face activities of teacher-learner interaction without the cost of a physical environment. So network connectivity and printed matter both share a primary role.
When considering the possible applications of a guided discovery approach, it has to be placed into the wider educational context. There are many other functions that can be added to offer other types of learning support. Therefore the system does not have to be able to provide full teaching capabilities, or to reject other forms of traditional teaching practices for distance learning. Instead a Guided discovery environment is only part of an encompassing approach to education which tackles other issues such as peer interaction which are outside of the scope of this project. It is the aim of this project not to build a complete curriculum, but provide part of a set of methods for learning that the student can select. It is suggested that if a hypertext-based tutorial is built it will rarely be the only way that the learner will learn about the domain topic although it can provide an essential grounding in the area.

6.4 Education Online

What is apparent is that the Internet is not only used in the realms of University and Computing research groups but also in the primary and tertiary levels of education. The most common use of the WWW is as an advertising medium. Schools could have a web page displaying pupils' coursework, or a university department may have a web page containing a list of papers and research interests. This move towards having a web presence seems to becoming a necessity rather than a matter of choice. In America schools are referred to as K-12 schools and join an educational network administered by the government controlling access to the Internet (Heaviside et al, 1995) and are able to display artwork or carry out projects in collaboration with other schools on the WWW.

However the WWW has provided more than just the means of obtaining a web presence. Several areas of WWW technologies for education will be examined in the context of how it can support different areas of education. The aim of this chapter is to provide an overview of the field to determine the place of a guided discovery system within this framework; in terms of the form that the learning can take, the advantages that it has and the role of the teacher and learner in these new methods for learning.
6.4.1 The Virtual University

The move is towards the 'virtual university' which is a higher education institution that may only exist online. A prominent example of such development is the growth of the Global Network Academy (GNA).

This was started in 1993 and its long-term goal was to create a fully accredited online university. It consists of a consortium of educational and research organisations who provide courses and degree programmes over the Internet (Butts et al., 1994). These are divided into subject areas such as the OnLine workshops which provide skills on how to use "MUD" ("Multi-User Dungeon") and "MOO" ("Mud Object-Orientated") sites for holding discussion groups (these are discussed in more detail in section 6.9.3). The GNA use a combination of email, MOO and WWW to support education. The Virtual School of Natural Sciences (Speh et al., 1994) is part of the GNA and develops courseware in areas such as BioComputing on the WWW. Other courses have been a self-paced hypertextual course on C++. In addition a classroom on the GNA campus is staffed with an online consultant at certain hours to answer student questions and help with exercises, with teacher support via email. The advantageous aspect is that the whole service does not need classroom contact.

The Global Classroom (Laslett et al, 1995) and the Global Schoolnet Foundation (GSF, 1996) support the idea of online teaching and many educational institutions are exploring the potential of the Internet to alleviate the problem of large numbers of students with a decrease in the amount of classroom space available. The suggestion is that as the number of students entering higher education increases, along with the requirement for greater cost efficiency, providing distance education over networks becomes increasingly appealing.

There are certain examples of developments in the United Kingdom concerning online education. The Scottish Higher Education Funding Council funded Clyde Virtual University (CVU) as an experimental testbed for developing and evaluating
techniques for delivering learning materials, to support collaborative learning and to carry out assessment (Whittington and Sclater, 1998). Those who wish to register are asked for a minimal amount of data and the CVU courses are not accredited unlike the courses for the GNA. But it does provide access to course material, online testing, email and discussion groups. Evaluations carried out by students and staff have been favourable, and CVU has converted courseware in a number of subject areas for delivery on the ClydeNet. The CVU project is continually being developed and remains a promising approach for creating the architecture for a U.K. virtual university.

Other educational institutions which have specialised in distance learning before the inception of the Internet have developed novel methods to add interactivity to learning. The KMI Stadium, created by the Knowledge Media Institute (KMI) of the Open University, is an experimental project to determine how to provide lectures over the Internet (Einstadt, 1995). A guest speaker is shown on the screen with attendees given the functionality of listening, booing, clapping or even falling asleep on the front row. Attendees can also post questions to the speaker and there are online discussions after the lecture, conducted in ‘virtual’ meeting rooms.

Projects such as the Learning for Life with Technology Project (Disney, 1995) emphasise the use of computers in everyday life for adult learners. There are many more examples of schools, colleges and universities using the Internet and those interested in this area should look at web resources such as the Regional Alliance Hub (TERC, 1994) as a starting point.

What is apparent is that there is a plethora of research in educational applications of the Internet with the impetus being to provide support for the student who may only have the computer as the main resource for learning. Mumford (1995), examining the issues raised in a workshop discussing the use of the WWW in UK higher education, surmised that:

“The WWW is clearly an important tool for many applications and is expected to do so for some years to come” (pp37).
In terms of teaching and learning there is a call for helping teachers to understand the pedagogic issues associated with this medium. The research carried out in this thesis can help inform courseware designers and teachers about some of the pedagogic approaches for Internet-based learning using a hypertext guided discovery learning environment. The principles developed can be applied to the creation of self-contained modules which can be taught over the Internet for learning. If the virtual university is the future of distance learning in higher education, as many proponents have suggested, then there is a need for establishing design principles and environments for the material to be taught as a self-contained course over the network.

6.4.2 Support For Teacher-Pupil Interaction

The WWW has been used as a means to support communication between the teacher and the learner. With a predicted decrease in the amount of face-to-face contact the pupil has with the teacher or with fellow classmates. The module, Taming the Electronic Frontier (Cox, 1996), is part of the MA in Telecommunications at the George Mason University, USA and provides an example of the many ways that the Internet can be used to support learning in the classroom. A Task calendar displays when lectures are; the results of the students' coursework are accessible to fellow pupils and assignments are given over the Internet to be submitted via email. The student has to contribute to mail lists and newsgroups, with 20% of the final marks being assessed using this criterion. Because student projects, books and articles are kept online most of the material needed for the course is available in electronic form with the shift towards the 'virtual classroom, composed of students who do not have to be physically present at the lectures or even visit the campus library. But the idea of learning remotely via the network for accessing web material has come under increasing criticism, with findings suggesting a loss of teaching support that has not been replaced by WWW technologies.

Research by Crook (1997) indicated that learners would not necessarily use the interactive components provided for use with hypertext lecture notes. It was argued that due to the increased ease of authoring web documents, lecturers were more willing to create and distribute their own teaching materials. Because these notes
could be accessed on the campus network, it was predicted that disseminating hypertext lecture notes would be an increasingly common practice among university academics. But it is suggested that just converting lecture material into web hypertext documents did not exploit the innovative potential of the hypertext format. As Crook (1997) indicates:

"students are being offered a bad model of the teaching relationship: passive absorption of pre-packaged authoritative notes" (pp.237).

Hypertextualising notes can detrimentally affect the way learning takes place. Crook investigated how undergraduate psychology students made use of lecture notes placed on the web, and ways that they could be extended to support interactive modes of learning. It was found that students did make extensive use of the materials placed on the web but that this was undermined by a strong desire to have a hard-copy version to study during lectures or at home rather than in front of the computer. Another significant finding was that students were reluctant to use bulletin board discussion formats or to send emails to lecturers for help even though they knew how to do so. Taken together these results by Crook suggest that there is a need to take into account existing educational contexts and social co-ordination when attempting to introduce new educational technology. A traditional lecture course will require a particular pattern of study which is different from browsing hypertextual material, while existing teaching practices can slow down the introduction of new material. The suggestion is that lecturers will continue to mount lecture notes on the web straight from a word-processed version without using the interactive functionality of the web. Just implementing computer-based resources is not enough. In some respects it could be regarded that students were receiving a poorer quality of teaching; due to assumptions about the web and how students would use this medium for learning. The use of email was also found to be linked to the learners' perception of what they thought email could provide for supporting learning.

A study by Trushell, Reymond and Burrell (1998), examined the use of email for a "tutorial" conducted for students in the U.K, by a guest lecturer located in France. The findings from this study on computer-mediated communication (CMC), indicated that tutees emailed questions that elicited information or clarification, rather than
viewpoints or opinions of the guest lecturer. Students viewed email as a less personal type of interaction, appropriate for types of tasks that require less social interaction such as asking for information rather than exchanging opinions. Therefore the use of email in supporting learning is problematic, and course designers who wish to use it must be cautious. The students may not use the email facility at all and if they do, it will be most likely used to ask factual-type questions rather than the opinions of the lecturer that could lead to a new level of understanding. The findings, although only at a preliminary level, indicate that placing lecture material is not enough to promote learning.

6.5 Principles for Designing Instructional WWW Material

A lack of design incorporating a structured, well-defined pedagogy seems to be hindering the effectiveness of the WWW as a supportive environment for learning. Hypertext remains lacking in established design principles for an educational context.

6.5.1 The Attraction of Hypertext and Why it is Not Enough

The potential of hypertext as a learning tool for the WWW is derived from the nature of the learning that it supports. It facilitates student-centred approaches, hence it is assumed to create a motivating and active learning environment (Becker & Dwyer, 1994). It supports and encourages browsing and exploratory strategies for learning, frequently associated with higher-order learning and higher levels of cognitive engagement (Rankin, 1992). The nature of information organisation in hypermedia is suggested as closely resembling human memory with retrieval methods purported to closely resemble human thought processes (Novak and Gowin, 1994). The WWW facilitates efficient information retrieval (Chen, 1998) and it is these, and other advantages offered by the medium, which have led to considerable enthusiasm among learning theorists and teachers towards the WWW and hypertext as a learning tool. As with all instructional technologies however, the potential remains unrealised with no established methodologies or results for the efficacy of hypertext learning environments on the WWW.
It needs to be understood that hypertext materials themselves do not teach but provide a medium which can support learning (Eklund, 1995). Considered in terms of a hypertext medium, the web offers no more than the representation of a hypertext information base, providing a means for representing interconnected segments of information, where the interconnections are usually associative links between nodes, and may be part of a complex semantic network.

Essentially the links in a hypertext information base are used to imply a relationship between two or more pieces of information, as well as to make explicit a pathway between them (Horney, 1993), but the information presented as web pages do not have a coherent and linearly constructed argument of the type that characterises knowledge represented in a paper-based medium (De Diana and van der Heiden, 1994). The associations of information found on a Web site cannot by themselves represent knowledge simply by implying a relationship between two or more items of information. It should not be assumed that the association of items of information equates to the construction of knowledge. For knowledge to be constructed, the reader has to make sense of the information association, by understanding the meaning of the association. Thus where the Web is used to represent complex knowledge types (such as concepts to be learned) it is important to make the associations or links between items or networks of information explicit.

Learning is achieved through a process of constructing knowledge. When a learner is confronted with new knowledge, the learner's intentions, previous experiences, learning styles and metacognitive strategies determine what becomes of the knowledge (Hedberg and McNamara, 1989). The effectiveness in any learning environment is based upon the types and levels of cognitive and metacognitive activity generated by the learners. Research has found that learning is enhanced by active environments in which students have cause to be engaged in processing personally relevant content and to be reflective during the learning process (Jonassen, 1994). Skilled learners are able to benefit from complete learner control (Steinberg, 1988) but some direction may be necessary for hypertext to be an effective educational tool as hypertext is essentially a passive environment (Landow, 1990; Laurillard, 1993). Structure alone cannot provide the support that the learner needs,
therefore tutoring material placed on the Internet should be interactive and contain a instructional element. The recommendation in this thesis is that the instructional element should be a guided discovery approach, which will provide the structure in the hypertext which is needed. The next section will look at general design issues which need to be considered in designing instructional material for the WWW, but will take a specific approach by isolating factors for building guidance into the hypertext environment.

6.6 Elements of Effective WWW Learning Environments as an Instructional Tool

In terms of the instructional design for the use of interactive multimedia programs for learning, it has been identified that the process of learning is influenced by a framework of three mutually constitutive elements: the learner, the implementation and the interactive dimension (Oliver, Herrington and Omari, 1996). The three elements correspond to the role of the teacher, learner and the materials themselves in the instructional setting. This framework is used to discuss the design of WWW materials for learning. Even though the factors for the learner and implementation issues are consistent with other types of computer-assisted instruction systems, it will be shown there are many unique attributes which can be applied to the design of instructional materials specifically for the WWW. These factors will be discussed as they are issues that need to be considered when designing instructional web material. Some critical considerations in designing instructional and informational materials for the WWW include: (1) structure, (2) orientation, (3) navigation, (4) presentation and (5) interactivity.

6.6.1 The Issue of Structure

A problem facing the WWW designer is to choose the strategy for organising the domain material. The different forms of hypertext can be described as a continuum based on the nature of the linking involved.
At one end of the continuum, there is minimal linking, with nodes connected in a specified sequence. This organisation of hypertext resembles conventional linear text structures. Subsequently the learner is encouraged to follow an instructor-led, linear sequence (Tergan, 1997). Further along the continuum, links can be used to form a hierarchical structure; with an increase both in learners control and choice of path through the hyperdocuments. At the other extreme, the hypertext can be a totally unstructured learning environment; with multiple links between associated nodes. In this environment, learners are free to move between associated nodes through referential links.

The choice of information organisation for WWW materials depends on the nature of the intended learning outcomes. Jonassen, Mayes & McAleese (1993) provide a guide for selecting the form of hypertext according to the nature of intended learning outcomes. Categorising specific instructional strategies can allow the formulation and prediction of particular types of learning outcome.

Therefore different forms of hypertext linking can be matched with instructional strategies and with certain knowledge acquisition aims. For example, linear linking can be used to develop students' initial knowledge such as facts, procedures and rules. For this type of learning the material should have strong structure. Learner freedom is almost negligible because users follow an instructional sequence set by the teacher.

For higher levels of knowledge such as developing an understanding of concepts and principles, less structured hierarchical and referential linking are more appropriate. Students are guided by factors such as prior knowledge and ability to assimilate new material. When building on an existing knowledge base, learners can benefit from the freedom to browse and explore, to inquire and seek responses to their own questions, moving away from following the pre-determined path of instruction set by the course designer. This is the arrangement of the hypertext structure used in this experiment, whereby learner are free to browse the material, but guidance is included in the same process, with system intervention if the user shows signs of being uncertain during navigation. As O’Conner (1995) argues, the imposition of structure into the hypertext will not necessarily lead to effective learning as:
"structure is not an automatic panacea".

If structure will not guarantee effective learning, nor will giving novice learners the ability to browse a wide amount of links (Mayes, Kibby and Anderson, 1990). What is suggested in this thesis is that an adaptive tutoring element should be incorporated into a structured hypertext organisation.

6.6.2 The Issue of Orientation

One of the major problems reported with the use of hypermedia as an instructional form is the orientation of the learner within the learning environment. Orientation describes the means by which users are able to identify their current position in the system, how they achieved that position and how to return to a previous position. Disorientation is a problem which is frequently observed in studies of hypertext users (Conklin, 1987) and a problem which significantly limits learning outcomes.

A number of strategies are available to the WWW developer to aid orientation within learning materials. These include: (1) Placement cues (these are bars or graphs interspersed within the text to indicate the distance and placement of the learner in the instructional sequence), (2) Hierarchies and Indices (these structures provide access to nodes together with an overall structure for the learner, often continuously displayed in separate frames and windows), and (3) as Semantic Nets (image maps allowing the connections between related information to be made apparent; therefore acting as a linking structure to reinforce associations and connections between concepts, as well as supporting learner orientation).

It is important when designing for the WWW to examine operational skills needed to move between nodes as this can also cause disorientation. WWW materials employ many functions and features that can distract the learner from the task at hand, so there should be a requirement to minimise the negative impact of poor interface design. When learners are compelled to consider how an interface operates when undertaking a learning task, there is increased cognitive load. Trying to cope with multiple informational sources reduces the resources applied to the actual learning task itself (Rappin et al., 1997). At the same time, if learners are not comfortable with
the system, it can lead to technostress (Shneidermann, 1987; Hedberg and McNamara, 1989), therefore making the instructional strategy less effective.

There are an increasing number of guidelines to minimise the amount of mental and cognitive activity associated with controlling the interface (Shneiderman, 1998). The aim should be to retain simplicity and consistency in design. When screens change, the only things that change should be the information to which the learner is being directed. Buttons and controlling features should remain in the same place and be intuitive. Typographic clues, colour changes and graphics can distract and should be used sparingly. As with text display, distinct guidelines exist to guide hypertext development for web pages which can help to minimise the disorientation problem. Nielsen (1996) in his design of the SUN web site provides a comprehensive list of guidelines for web page design. Interface design considerations are discussed in chapter 8.

6.6.3 The Issue of Presentation

In designing instructional material another critical aspect in WWW content presentation is text structure and its readability. Readers find coherent and well-structured text easier to read than that which is less well defined (Gillingham, 1993). Structured text provides information in a sequential fashion with elements such as overviews, and a consistent format to which subsequent text can be added. Some strategies for developing hypertext as well structured, coherent and readable texts are: cues, overviews, nets, and hypertext links to further explain particular parts of the hypertext. Appropriate indexing methods such as paraphrases, summaries and contents pages can control fragmentation (when the learner sees the information elements as separate rather than as a linked whole). As well as displaying anchors and destination nodes at the same time, so that the learner knows how the links are connected.

6.6.4 The Issue of Interactivity

Interactivity has been described as an important component for promoting learning but its use has only now begun in an educationally effective manner for the WWW.
Interactivity describes the forms of communication which a medium provides for enabling dialogue between learner and instructor (Jonassen, 1988). With computer-based learning environments, communication between instructor and students is constrained by the technology. The technology (sometimes an intelligent tutoring component) is used instead of the instructor, with exchanges taking place between the learner and the programmed instructional system. It is suggested that system feedback will enhance learning (Brusilovsky, 1996).

Interactivity remains difficult to achieve with WWW documents as studies suggest that clicking on nodes and navigating in an instructional sequence is not representative of interactivity (Eklund, Brusilovsky and Schwarz, 1997). Some strategies that have been used with cautious success to create interactivity in WWW learning materials include the online discussion of answers and e-mail communications (Crook, 1997; Trushell, Reymond and Burrell, 1998).

Other forms of interactivity have begun to appear with the continual development of web technologies. The use of Common Gateway Interface (CGI) scripts at the server side enables designers to create forms within documents to receive learner responses and return programmed feedback. Multiple choice and short answer tests can be automatically marked and record-keeping can be collected for more advanced student diagnostics and administration purposes (Debreceny, Ellis and Chau, 1995). The section, Online testing, in section 6.9.5, provides a detailed review of current testing systems and the assessment used in this experiment.

New developments in client-side processing applications have also led to enhanced interactive capabilities for the WWW. The advantage of client-side processing is that learners can receive immediate feedback to interactions whilst using less server resources. For example, building Java applications operating through the browser can lead to many forms of interactivity, with Pang and Edmonds (1997) providing a comprehensive review of Java and its potential applications for learning on the WWW. The continual release of web browser plug-ins such as Shockwave and PUSH technologies (which automatically feeds information to the user similar to watching television) now support increasingly sophisticated processing of learner actions and responses.
Eaton (1996) examines interactivity in WWW from the dimension of social interaction. Individual interaction is interaction between the individual and the learning material and social interaction is interaction between two or more people concerning the learning material. Eaton views both forms of interaction as necessary for learning; and that they should be retained in the design and technology used for distance learning presentation. A central problem is that the effectiveness of the system for negotiating control with the learner maybe insufficient. There has been unanimous agreement among distance education theorists that two-way communication (between teacher and student) is an essential element in distance education (Debreceny, Ellis and Chau, 1995). Students in distance education are learners who have chosen this mode of study usually because of the flexibility it offers, but classroom interaction is lost for this gain in flexibility.

The solution may be to allow the student to communicate with the instructor. In traditional CAI, the student can normally discuss with the teacher in class; but in distance education, the common way is to use telephone, e-mail, or written correspondence, thus delaying the learning process. HTML/CGI forms technology can allow the learner to add hypernotes or change the hypertext. The instructor can examine this and is able to monitor the progress of the students as they interact with the CAI by looking at user history files stored on the server. These technologies can be used to gauge student progression, identifying student problems early on. Therefore interactivity can support learning but in several ways; from supporting the learner during the actual learning process to providing social contact with an instructor. Therefore interactivity can exist in several forms from the material itself to communication with others. This project has tended to concentrate on a self-sufficient course but it can be used as part of a wider support environment.
6.7 Designing Learner Roles

There are many ways in which the role of the learner can be varied within an instructional setting that can lead to positive learning outcomes. Certain student behaviours need to be considered when designing WWW materials.

The promotion of learner reflection, in the design of instructional web material can be beneficial to learning. Activities which encourage reflection and metacognition through increased levels of learner control may make students focus more attention on their own thought processes (Collins & Brown, 1988). Learning programs usually subdivide skills into smaller sections which are then taught systematically in a logical order. Students can deduce the answers correctly from the preceding section without a real understanding of the subject, and therefore no need for reflection. More effective environments for learning should require students to draw upon a broader knowledge base for problem-solving. To carry out problem-solving or task completion, the student could be required to reflect by predicting, hypothesising, and experimenting while searching for a solution. Using more hierarchical and referential links and associations in hyperdocuments will help reduce the linearity of the navigation, forcing learners to actively seek out an answer.

The role of the teacher changes with the introduction of web technologies. There are educational advantages for organising collaborative activities among students. The communications component of the WWW provides opportunities for enabling different forms of communicative and collaborative activities among networked learners (O'Connor, 1995). Shneidermann et al. (1995) discusses the benefits of “Learning Theatres” whereby the teacher takes the role of a guide with the students in an electronic classroom, composed of computers at every pupils desk connected over the Internet. The result being that entire class collaborative learning sessions lead to high levels of engagement. This work be seen in the context of learning using a network rather than of guided discovery, as this was not used as the specific style of teaching. The implications for using the guided discovery condition for collaborative learning is discussed in the Conclusion (chapter 11) but the system in this project is primarily designed for single user conditions.
6.8 Planning Implementation Strategies

The third constituent element of an effective WWW learning environment is the role of the teacher and the procedures by which the learning materials are implemented. To enhance teaching and learning with the WWW, coaching, scaffolding and integrated assessment are possible methods of instruction.

6.8.1 Coaching and Scaffolding

Coaching is the action of the teacher in providing guidance and help in a setting for learning, whilst scaffolding represents the support provided in the form of skills, strategies and links which students need to complete the task. The tutoring process usually takes the form of strong support initially (the scaffolding) and then gradually decreasing this as the student progresses through the material. The teacher's role in coaching, student tracking, offering hints and reminders, scaffolding and fading intervention can support many types of learning situations.

Designers of WWW instructional materials attempt to predict everything the student may need to learn for a particular topic and create documents that are self-contained resources. However, there are many individual learner characteristics that cannot be accommodated in a single WWW document, such as learning style or different learning goals. There have been some attempts to create intelligent systems for the WWW, such as the work carried out within a new field of research, Adaptive Hypermedia Systems (Eklund, 1995; Eklund, Brusilovsky and Schwarz, 1997), although currently, this role of modifying material to suit learners continues to be performed best by the teacher (Oliver, Herrington and Omari, 1996). Adaptive Hypermedia Systems will be discussed in Chapter 7 as a contributory area for WWW and learning. The principle of decreasing intervention is included as part of the strategy of the guided discovery experimental condition in this project. With greater support of the learner during the initial navigational process, and with a decrease in system intervention as the learner carries out more online tests and progresses further
in the domain material. The proposition is that conventional hypertext is not able to provide the support that is needed by novice learners (this has already been discussed in greater detail in section 5.7.2 and 5.7.3).

6.8.2 Online Integrated Assessment

Measures and assessments of achievement and outcomes are an essential part of the teaching and learning process. Computer-based assessment often has little resemblance to the environment in which the learning has occurred. It is suggested that future educational environments should not view assessment as add-on but instead be part of an integrated learning environment. The attraction is to return to traditional paper-based written exam and practical tests, due to a lack of research into assessment able to use the capabilities of the web (Debreceny, Ellis and Chua, 1995).

The increase in interactive capabilities of the WWW (in relation to earlier Internet browser technologies) provides the means for assessment of student learning; rather than a reliance on conventional essays and examination submission. McLellan (1993) points out that more reliable assessments can take the form of evaluation measures such as portfolios, summary statistics of learners' paths through instructional materials, diagnosis, and reflection and self-assessment. Pang and Edmonds (1997) consider ways in which Java can be used to take free-form answers, graphical drawings and simulate scratchpads. Multiple-choice testing used in hypertext research (in chapter 8) is also applicable to the design of WWW documents and learning materials. This is discussed further in section 6.9.5 which examines immediate testing rather than long term assessment.

6.8.3 Time Delay: the Effects of Network latency on Learning

There has been little research on the effects of a delay in web page loading time and learning. This suggests a gap between hypertext research and the WWW, as hypertext research has shown that system response time is recognised as a major stressor in HCI, with an overly long response time resulting in a degradation in user performance. Response time is defined as starting from the moment that the user initiates the activity to when the computer begins to present the results on the screen.
It has been shown that 10s of seconds were seen as the maximum wait for many users. Those on the web have to wait far longer.

A survey by Pitkow and Kehoe (1996) reported that three quarters of their respondents answered that a major problem was waiting too long to download web pages. A much smaller pilot study than this survey was carried out by Byrne and Picking (1997) confirming that time delay was regarded as important by web users, although the dominant issues were still navigation and web page design. The web pages used for this experiment were retrieved from a local on-campus server, so the delay might not be so apparent. Nielsen (1996) has cited response time in his list of ten biggest mistakes in web page design, therefore it has begun to gain recognition but not to the extent that it should.

An experiment by Ramsay, Barbesi and Preece (1998) found several conclusions about the effects of time delay. Although their sample was small, consisting of twenty regular student web users, it was found that there was a significant difference between the user's perception of the value between the quickest and slowest loading pages. Pages that were retrieved faster were judged by the subjects to be more significant and interesting than the slower counterparts. The conclusion that they drew was that the longer the subjects had to wait for a web page to load, the greater the boredom and frustration experienced.

Research from Parker (1997) determined that acceptable interface response was divided into two criteria: (a) that the timing of the web behaviour conforms to users' expectations, formed from past experience or current feedback, (b) the experienced user does not have to devote any conscious attention to the timing. If these two criteria are fulfilled then there is no delay. Parker suggests that findings from the psychology of time should be applied to an analysis of the temporal effect on computer applications uses these two criteria. To compensate for this delay, experienced users would attempt to optimise browser performance and the less technical user would just avoid sites that took a long download time or used frames (McManus, 1997). Therefore delay in the loading of web pages seems to be a real problem that affects interaction with the system and it is predicted to become worse as web pages become graphically-intense with more functionality embedded into the
web pages. A workshop entitled “Time and the Web” in 1997 (Gaines, 1997) was held to look at the difficulties of time delay, and although it did not look specifically at educational effects, it did provide a comprehensive discussion of some of the major research issues that are currently being investigated. But there continues to be a distinct lack of research into the effects of time delay for learning.

The implications for this experiment is that frame updates, user tracking applets, online testing and creation of system intervention would all contribute to a lengthier download time than the other experimental conditions often do. If this were the case then it would be captured in the user satisfaction survey administered after system use and in the interview afterwards. This could be a possible explanation for any degradation in performance if the subjects in the guided discovery condition were to display lower gains in learning and higher dissatisfaction with that particular condition. There remains a paucity of established data on how unpredictable and lengthy retrieval times affect users’ perception of web pages. It is suggested that frustration, due to lengthy delays (if they do occur), may contribute to any reported dissatisfaction with the guided discovery system and may even result in lower learning gains. Findings from hypertext research should be applicable to this area, and there remains an increasing requirement to examine this problem in the light of building systems for learning on the WWW.

6.9 Other Forms of WWW Educational Support

As the popularity of the WWW has grown so has the possible ways that it has been used for educational purposes. Some of the more popular applications are described to demonstrate some of the advantages and disadvantages of carrying out education using the Internet.

6.9.1 Electronic Classrooms

The virtual classroom provides many functions apart from the presentation of the course material. It can contain pages for lectures, information on courseware,
students and teachers. Each lecture consists of explanations on the subject with links to study in-depth related arguments and related bibliography. The information on students and teachers consists of their curricula and how they can be contacted for queries and for collaboration. Moreover, teachers are able to send explanations via email which can contain textual data and also software applications, bibliography and hypertext links. The teachers can use tools for co-operative work and create groups to work on a particular lecture subject. This collaboration is carried out via the network by exchanging files; and teachers can periodically hold a conference with students to determine progress.

The virtual classroom is also used to hold exams for groups of students, in order to estimate co-operative group work skill; or for single students to determine possible gaps in the learning process. The basic aim of the educational environment is to offer a student-centred learning environment which is satisfying in terms of subject explanation. The exams are needed to check the learning skills of the students, and to provide them with effective feedback. Both Bilotta et al. (1995) and Shneiderman et al. (1995) provide comprehensive discussion of case studies of the value of virtual classrooms.

6.9.2 Educational Networks and Support Groups

HyperNews is a web based conferencing system which allows for interactions similar to those of UseNet Newsgroups. It is used at CVU to support general discussion groups and specific ones such as a Java developers group (Whittington and Sclater, 1998). It has been shown that HyperNews can help students learn by providing material not available from course notes or lectures. This can be used to allow students to see what their peers are doing and creates greater motivation to participate in coursework.

6.9.3 MUDS and MOOS

Educational institutions are experimenting with the idea of educational MOO sites (Newberg et al, 1995). MUD and MOO sites have only recently been used for educational purposes to aid learning. Originally named MUDS (Multi-User
Dungeons), the Object Oriented Multi-User Domain (MOO) software were initially developed for role-playing games in which players interact with each other and a computer created fantasy environment with a selection of simulated objects and characters. These virtual worlds change the notion of identity allowing users to adopt different identities to carry out role-play in various scenarios and simulations.

Recently MUDs and MOOs have been used to support scientific and political communities. BioMOO is a scientific research site, which has facilities such as a virtual room to examine and dissect virtual mice; and also speaking and interacting with other scientists in the same room (Newberg, Rouse III and Kruper, 1995). The next generation will incorporate a web and MOO facility to support network-based learning environments. These new environments will no longer be restricted to text access (the previous means) and will instead use hypertext and hypermedia capabilities of the web. Most of the courses organised by the Global Network Academy (Butts et al., 1994) emphasise this as a method of discussing ideas amongst classmates, and some of the courses regard participation as essential and is therefore assessed. Newberg, Rouse III and Kruper (1995) have examined the future potential of a combined web/MOO environment and have built Phoenix, an authoring tool for constructing such systems. The potential for these types of technology are still being explored. Because of the possibility of having a web capability, it may be beneficial to have a MOO component integrated alongside a guided discovery learning environment to further support user queries. At the moment this is only a suggestion as there has been no systematic research into the benefits that an integrated WWW/MOO environment will bring.

6.9.4 Information Repositories and Virtual libraries

Marchionini and Maurer (1995) predict that what will influence teaching and learning in the future is the growth of digital libraries which will provide background resources which authors can use to construct courses and learners can use to explore further information. Network technology provides the final breakthrough for computer supported learning because firstly it makes access to material easier, and secondly it allows feedback between all the parties in the educational process. Digital libraries provide structured repositories of material that can be used for authoring and creating
courseware. This will play an increasingly crucial role in computer-supported teaching.

Making materials available electronically on the web - which were previously only available in paper form - will offer additional benefits. The growth of electronic journals in a hypertext mode means that there is up-to-date information, search facilities, inclusion of multimedia and more interaction and feedback from the writers and readers. Traditional reference material such as books, dictionaries and encyclopaedias have become increasingly available with the addition of multimedia material. What is clear is that major collections of data stored in digital libraries will be available for use by teachers and students.

There will be crucial changes in terms of authoring course material and in the learning process itself, when using the WWW. There will no longer be a need to start from scratch when creating a teaching course. Integration of a multitude of digital information ranging from sound to motion can be combined into a modern hypermedia system. It is suggested that the courseware produced is also different in terms of the control it offers to the learner. Learners are now given a strong thread to follow throughout the courseware, but they can browse through other material in-between when they feel it is necessary. This is similar to the guided tour approach (Trigg 1988; Bush, 1967). Marchionini and Maurer (1995) conclude that the guided exploration paradigm has a potential advantage over other paradigms that have only been moderately successful in the past.

6.9.5 Online Testing

When delivery is provided through traditional on-campus means, regular paper-based testing and prompt feedback of the information is relatively straightforward. With a student population which is geographically distributed testing and assessment alternatives are limited by the current technologies. Nevertheless creative solutions are possible and require further investigation before falling back on traditional methods such as the written examination or the practical test (Debrecheny, Ellis and Chua, 1995). As an example, the WWW now provides the opportunity to deliver multiple choice tests in those disciplines which contain a high factual content with immediate processing and feedback (Byrnes, Debrechny and Gilmour, 1995).
In the WEST Project (Eklund, 1996), students’ results on online testing modules were used to provide individual navigation support by the system; to guide the learner through the courseware. The system was built using JavaScript and Filemaker Pro, incorporated into a Web-based learning environment which offers individualised navigation support to students. The aim of the work was to allow the system to test the student’s knowledge and track their progress through a learning space and to represent that progress visually and individually for each student.

The WEST system used a Netscape frameset dividing the browser into smaller frames (windows), with a smaller bottom frame depicting an individual overview map of the nodes in the hypertext for that particular student. This map shows students where they are and where they have been. Based on auto-marked online questions embedded in the courseware the map annotates to where it "suggests" they should proceed. The colour of the hyperlinks also change according to where the student had previously been, and the current position in the material (green for the current page, red for visited, blue for unvisited). Using results from a multiple-choice online test; the hyperlinks will 'blink' to suggest to the student to either proceed further or to review previously encountered material. Therefore this clickable overview map can be used to direct, or suggest, to the learner where to go next, hence supporting learning choices as well as orienting the learner. This can be regarded as a visual cue for navigation and system-directed guidance.

When the Clyde Virtual University (CVU) was initially being developed, a CVU assessment engine was developed to provide online testing (Whittington and Scalater, 1998). The predicted purpose of using web-based technology was to enable the automatic delivery and marking of multiple choice questions, provide feedback for the students and to allow student administration information to be collected. It was suggested that this would add an interactive element to tutorial material and would also provide summative assessment. Rather than just allow the students to work through pages of course material, meaningful learning would be encouraged through the carrying out of interactive tasks. The next stage is to develop a wide range of question types such as multi-choice, multi-response, gap filling, list ordering, matching pairs and free form text but this still remains at a developmental stage.
Online testing is discussed in terms of the guided discovery system for this thesis in chapter 8.

6.10 Summary

The research literature described in this chapter has focused on the design of WWW web pages for learning, examining how to plan and develop the domain material. Although this is an important activity, there has been a lack of consideration of two other factors in the learning process. From a design perspective there needs to be equal emphasis on the learners themselves and how the materials will be implemented.

This chapter has focused on the virtual university as it is envisaged that this will be part of the educational environment in which a guided discovery system will be used. Consideration of the learner has been discussed in the section on the growth of distance learning and the reasons why this has occurred. This has been followed by a discussion of ways that WWW can support learning and education. The latter part of this chapter has provided guidelines for the design of instructional material for the WWW that can support the different factors that comprise the components of hypertext-based environment on the Internet. There should be consideration of how students learn from hypertext, and the differences the WWW would impose on this process (this is discussed in more detail in chapter 7).

Learning achieved through use of the WWW depends not only on the quality of the learning materials but also on the ways that they are used by the learners and have been implemented by the instructor. There must be a consideration of these interconnecting factors when evaluating WWW and learning. The best WWW materials can be completely ineffective when used in the wrong contexts and with inappropriate implementation. Therefore this chapter has been used to suggest that when designing a learning environment, there needs to be a consideration of a multitude of other factors from a design perspective. The specific factors which separate the hypertext environment in this project from a conventional hypertext environment is the application of a guided discovery approach for the design and operation of the system for promoting learning.
Chapter Seven

The Internet as Educational Hypertext

7.1 Introduction

The Internet has grown at an exponential rate. With this has been an increasing interest in the use of the World-Wide Web (WWW) as an environment to promote learning. There have been many variations of learning, from the idea of the virtual university to the use of virtual worlds, all concerned with the premise of delivering distance learning (see chapter 6). Such instruction either serves as a replacement to whole courses or as a substitute for less time in the classroom, strengthened by teacher support via email or videoconferencing. In terms of hypertext systems, it has been argued that the advantages of using hypertext, has been transferred to learning from web pages. Therefore there are a combination of research issues when designing a guided discovery learning environment on the Internet. Some of these issues existed previously in hypertext research, but some are specific to the Internet itself.

The main strength of hypertext to browse the material remains a distinguishing characteristic of both hypertext and web pages. Navigation and disorientation issues remain at the forefront of research into hypertext systems that use the Internet to carry out learning. This section will begin with a discussion of the components that make up the Internet followed by a discussion of the size and growth of the Internet and the World-Wide Web. This will illustrate that, although WWW-based learning is still in its infancy, that the potential is there for those who are at a distance to be connected to an online environment for providing individualised instruction; and to use it for learning purposes. This will be followed by a discussion of research issues related to hypertext and the web. From this will be a discussion of Intelligent Tutoring systems and learning environments that currently exist on the Internet, identifying their strengths and weaknesses. The discussion will centre on the proposal for a tutorial
element to be included, with some of the suggestions advocated by adaptive hypertext being used to feed into the design of a guided discovery environment. Chapter 6 discussed the issues of learning in the context of distance education, with an examination of general effects of using the WWW. This is linked to this chapter, but this chapter looks specifically at hypertext applications. What is apparent is that the use of hypertext in WWW educational systems, is still in its infancy (Benyon, Stone and Woodroffe, 1997).

Many assumptions have been built into the design of systems for teaching and into hypertext and there remain no established methodologies for building learning environments for the web. It is suggested that the findings from this thesis will contribute to principles for building a learning environment able to support the cognitive processes of learning, in an environment that is continually increasing in functionality and furthering its possibility to support learning. Therefore there are twin issues; one of hypertext and the other of using the Internet. The problems encountered in using hypertext and the research citing these problems have already been discussed in earlier chapters (see chapter 5, Major Issues in Hypertext).

### 7.2 Structuring Information in Web Pages and Hypertext Documents

Information in WWW is commonly structured as web pages; with documents linked together according to the hypertext paradigm (Conklin, 1987; Tomek and Maurer, 1991). Navigation in WWW is performed using the hypertext functionality of anchors and links. The previous chapter (chapter 6.5.1) concluded that different organisations of links could affect learning outcome. Past research has suggested that the nature of the WWW makes this principle problematic to apply.

In a hypertext system, information is stored in "chunks". Chunks consist of individual documents which may themselves consist of various types of "media" (Elliot et al., 1995). Typically a document may be a piece of text containing a picture. Each hyperdocument may contain links leading to parts of the same or different documents.
Typical hypertext navigation through the information space is based on these links; with the user browsing a sequence of links for relevant information.

In the WWW, a "chunk" consists of a single web page. Web pages are composed of textual information and may include pictures and links anchors (source). Anchors can be attached to textual information and images. In terms of multimedia, these can also be incorporated as links that activate audio or video clips. The textual component of a document is stored in HTML format. Therefore it could be argued that because web pages perform similarly to educational hypertext, that they are able to promote meaningful learning in the same manner that it is claimed hypertext can.

This issue is contentious as these areas, hypertext and the Internet have inherently different characteristics. The use of the WWW for pedagogical purposes has been discussed by Ibrahim and Franklin (1995). The distinction that they draw between different types of systems for learning highlight different issues which should be borne in mind when designing Internet systems for education.

It is suggested by Ibrahim and Franklin (1995) that just browsing through the web is already a pedagogical experience. Internet users have started browsing with a specific goal but often become distracted from that initial goal because they had followed other links that they had decided had held interest. There are however structured ways in which the WWW can be used for education. Two main approaches can be used when designing systems and Ibrahim and Franklin argue that pedagogical uses of the web can evolve along these two major axes: the first is the use of technology on a closed corpus of educational material, utilising hypertext and distance delivery capabilities of WWW. The second approach is on the use of technology to access, in a structured manner, an open corpus of material which was not initially intended to be used for that specific educational purpose. These will be briefly examined to examine where this research fits in the spectrum of systems currently being implemented, to determine how conventional hypertext systems are different from web-based systems.

A closed corpus of information is often in the form of online courses that take advantage of the WWW's hypertext capabilities. This is usually combined with fill-
out forms, to create educational material characteristic of regular courseware; but with the additional advantage of remote accessibility. It is composed of material specifically designed for a particular course. It can be regarded as self-contained in that the learner does not need to explore the Internet to gather supplementary material.

This is in contrast to the open corpus of material. The course designer and teacher will select repositories of information for the learner to explore but these are located in many different places. Some of the material may not have been purposefully made for the course and the use of it can involve search engines to locate the necessary information. Open and closed organisations of information are not mutually exclusive and have been combined to form different sections of a course. This research focuses on a closed corpus of information. It is suggested that some of the principles from examining closed corpus systems will also be applicable within the open corpus context.

A problem that is specific to the WWW is that the hypertext transmission protocol (HTTP) is stateless with no direct relationship of any kind between two consecutive requests to the same server, even if the queries originate from the same client. The server treats every request it receives independently from any other request, making user tracking difficult with no identification between a specific user and the web page requested. The use of cookies (sent by the WWW browser to the server to identify a retrieved web page by a particular computer) relies on this function being switched on by the user and is not always passed on by the WWW browser. At best it can provide a partial record of a user's navigation history and remains linked to the computer rather than to the particular users themselves.

It is suggested in this thesis that there is a need to account for the background of each learner by keeping individual records of user progress to base decisions system interventionist strategies. To be able to tailor the systems behaviour to the learner's capabilities and past history and to provide appropriate remediation to learners experiencing difficulties understanding particular concepts. The guidance mechanism carrying out this user tracking is described in chapter 8. Therefore it will be shown in this thesis that a guidance aspect needs to be embedded into the web pages, to provide for sufficient cognitive support to promote meaningful learning.
In terms of learning in a closed hypertext system, the information space that the learner can explore is often reduced resulting in less cognitive overload during navigation and less possibility of disorientation. In an open Internet system, the documents can reside anywhere around the world, with a seemingly endless amount of links to follow. Therefore the load on the cognitive abilities of the learner to keep track is increased, as is the possibility of being lost. Therefore it is hypothesised that a guided discovery system will be able to alleviate these problems while promoting active learning in a closed corpus scenario.

7.3 Pedagogical Approaches to Learning using the WWW

As more users have joined the Internet, so has the recognition of the potential that Internet technologies have for distance learning. In this regard the WWW has greater appeal because of its hypertext capability. This hypertext capability makes the WWW educationally attractive due to the claims that hypertext has for promoting learning. Added to this are other features such multimedia documents; but of more importance in terms of this research, is the ability to support distance learning using the networking basis of the WWW. Therefore the challenge for educational developers is to combine knowledge of learning, together with an understanding of the features of the WWW. To design learning experiences which facilitate cognitive engagement with the domain material.

Desirable learning outcomes for online learning systems, and education generally, have been: (1) a deeper understanding of the subject content, (2) the ability to analyse and synthesise data and information, (3) the development of creative thinking, and (4) improved communication skills. There are a number of features of the World-Wide-Web that have determined the way that it has been used for teaching and learning. Four of these approaches will be discussed.

The most common approach in using hypertext for teaching and learning on the web is to create documents containing hypertext links that the learner follows in a
sequence often unique to the individual learner. This is a major feature of the WWW, to allow developers the potential to create links between text and other media, not only within an individual document but also between documents residing on any computers in the world which have Web access. This resembles the open corpus scenario outlined by Ibrahim and Franklin (1995). The provision of this non-hierarchical linking has been claimed to provide a number of advantages to learning.

The most educationally attractive is that the learner is given freedom to browse the material, retaining control and interacting with the environment. It has been suggested that the structure of hypertext matches human cognition; in particular, the organisation of cognitive processes such as memory (in the form of a semantic network in which concepts are linked together by associations). Jonassen (1988) suggests that because hypertext is a node-link system based upon semantic structures, rather than sequential access, hypertext can map fairly directly the structure of the knowledge.

But there have been questions over the extent to which it is possible for students to acquire the original author's structure and map it on to their own existing structures. Learners develop individual interpretations of information and hence construct their own meaning. Since it is rare for two people to construct the same 'semantic structure' it is therefore unreasonable to expect that a learner could easily adopt the author's structure and meaning (Alexander, 1995). This criticism has also been levelled at the creation of teacher-prepared cognitive maps for the learner to use, rather than allowing them the facility to create their own.

There are also questions over whether hypertext structures do resemble that of the semantic structures as there is a lack of established research from cognitive and educational psychology to confirm this assumption (Tergan, 1997; McKendree, Reader and Hammond, 1995). Therefore the assumptions built into hypertext, and which have come to be used in web pages, can be criticised as suffering from the same lack of established data about the efficacy of educational hypertext for promoting learning.
A second approach to the use of hypertext programs is to take advantage of interactivity, a capability which it is claimed provides a useful strategy for active learning. Laurillard (1993) disputes the value of hypertext for providing interactivity. A conventional hypertext system does not provide any feedback and the web pages remain the same regardless of the individual learner. Mayes (1992) examines the assumption that hypertext provides a high degree of interactivity.

Interactive learning is widely assumed to be effective because active learning produces positive learning outcomes. But Mayes questions the idea that interactivity is a necessary attribute of effective learning with computers. The dimension of adding interactivity for promoting better learning has rarely been questioned. What is required is a more critical analysis of interactivity to identify the essential features which lead to effective learning. The argument is that the provision of hypertext links in documents simply enable the learner to follow paths that are pre-determined by the author and that this activity is not useful either for apprehending structure, or for providing action and feedback. It is simply ‘re-packaging’ - taking an existing book (with or without pictures) and simply adding hypertext or hypermedia links (Alexander, 1995). In section 6.5 it has been shown that many online learning systems which claim to promote learning do not provide the necessary support; that they resemble lecture notes but in a hypertext format, and the ability to browse is not seen as sufficient to structure learning.

A third approach to the use of hypertext/hypermedia links on the Web is to encourage learners to become collaborative authors. Opportunities are provided for learners to contribute to the construction of documents on the Web by attaching their own data in the form of written and oral commentaries, images, or alternative links which are available for other learners to read and follow. Learners are exposed to variations in interpretation and construction of meanings as they review evidence and arguments, to develop an individual interpretation of reality. This also encourages development of the desired learning outcomes referred to earlier: the ability to analyse, to gather evidence and to synthesise. Collaborative groupwork over the Internet is not investigated in this research, although it is a possible use in the future for the guided discovery system.
A fourth approach is to collect a range of Internet information sources to provide an integrated learning experience. This is the approach adopted by the JASON project (Alexander, 1995). The project provides many ways to get related information using discussion groups, home page updates, remote camera pictures, and Gopher resources to direct learners to related information. The learner is allowed to choose which links to follow and the different types of presentation used are more interesting than reading pure hypertext (Alexander, 1995). But no real guidance is given about the most beneficial 'path' that a novice should follow. Therefore the learner can end up just browsing, searching for what is perceived to be relevant material.

In terms of Ibrahim and Franklin's (1995) division of educational systems for the Internet, the closed corpus approach resembles the traditional distance learning approach and focuses on using the hypertextual and remote access capabilities of the WWW, whereas the open corpus is more oriented towards open learning and focusing on the information that is accessible on the Internet. Figure 12 displays the position of guided discovery in these different collections of learning material.

![Guided Discovery Diagram](image)

**Figure 12: The Position of Guided Discovery according to the corpus of the Learning Environment (Ibrahim and Franklin, 1995)**

It can be seen from figure 12 that the different dimensions provide different approaches by the user towards learning on the WWW. Guided discovery learning
can be used in a learning environment that involves a mixture of both open and closed corpus web document resources. The combination of the two strategies is predicted to produce educational material which has not previously been produced by any other medium (Ibrahim and Franklin, 1995; Alexander, 1995).

### 7.4 Navigation Issues for Hypertext and the Internet

The WWW is educationally attractive because it can allow easy re-use of existing material to convert to hypertext (and the use of Internet browsers makes configuration easy). But it remains essentially a passive and static medium in which there are limited means to guide or help students to move from web page to web page when navigating the WWW hyperspace. This problem already existed in earlier hypertext systems (Landow, 1990; Laurillard, 1993).

A fundamental limitation of this approach is that not all students are typical. The sequencing of the web material and the links are fixed, and not dependent on the individual user's responses or actions. Unlike Intelligent tutoring systems, hypertext-based systems are commonly a static, non-adaptive learning medium. They do not teach, but instead provide the student with the opportunity to learn of their own accord, and have been described as a non-pedagogical technology, because they possess minimal structural knowledge of content (Duchastel, 1992).

The shift in learning and the Internet is to build an interactive educational environment on WWW. In order to build a system that is more than a textbook form of lecture notes; it is necessary to embed an adaptation component able to actively guide the learner through the hyperspace, taking into account factors such as background knowledge, learning styles and other individualistic factors (Nakabayashi et al., 1995).

Navigation issues in web use are similar to those for hypertext. These have previously been discussed in chapter 5 and will only be briefly covered here. What remains prominent is that it is completely up to the user where to move in the WWW
hyperspace (as in hypertext systems). Although given the freedom to determine a path through the material, there is often no way to guide or assist the learner. It is this requirement for effective tutoring that influences the system used in this experiment. The research issue is to examine ways to structure the discovery process so that the learner can understand the relevant concepts regardless of the learning style of the user. The integration of cognitive tools will offer some support for processing the information and for the navigation process.

Hypertext will allow the learner to traverse the hypertext in a non-linear manner carrying out actions such as clicking on web links or hotspots. This node-link structure has led to the investigation of new issues about the model of learning on which the media is based, and the principles to be embodied in the design of hypertext-based systems in order to promote and maximise learning. It is this issue of navigation that provides hypertext with both its benefits and its criticisms in general hypertext applications, as well as for learning (Jacobs, 1992; Nielsen, 1990; Jonassen & Mandl, 1990). In the educational domain, hypertext will allow complete learner control over the viewing of the material. It has therefore been viewed as a cognitive tool (Mayes, 1992; Jonassen, 1993), with the learner constructing personalised meaning in a motivating and self directed manner.

Some system-led direction may be necessary for hypertext to be perceived as an effective educational tool and having some benefit by the learner (Elliot et al, 1995). It has been found that when the hypertext system allows free exploration, learners tend to make poor navigational decisions (Jonassen, 1991; Jonassen & Wang, 1993). This could be due to individual factors such as background knowledge that negate any effect that the hypertext structure will have on the learner (Steinberg, 1988). Learners may become lost, miss out important content, avoid answering questions, and use the navigational features haphazardly.

Browsing can result in incidental learning. Users can browse along hyperlinks, explore the information space, encountering 'chunks' or nodes of information that they would not have requested in a formal query (Brusilovsky, 1996). If the hyperspace is very large and when the system is used by people with different goals and knowledge levels, there is an overly high risk of unproductive wandering, or 'web
surfing" which is not optimal as a strategy for learning. The solution to this is to possibly incorporate a form of expert assistance or guidance (Duchastel, 1991; de La Passardiere & Dufresne, 1992). This could take the form of individualised navigational advice, or help sequences to provide greater structure to the information space. Providing more direction for the user, to help reduce these problems of disorientation is part of the research hypothesis of this thesis. The area of adaptive hypertext will be examined next to discuss some of the recommendations that can be derived from this approach to WWW hypertext environments.

7.5 The Contribution of Adaptive Hypertext to Educational Hypertext on the World-Wide-Web

Adding control through an intelligent component seems contrary to the underlying principle of hypertext that is supposed to give the user full responsibility over exploration of the information space. ITS are knowledge centred and have the ability to individualise instructional sequences by modifying content or presentation based on the interactions with the student. This is in contrast to hypertext systems that are predominantly a non-pedagogical technology (Duchastel, 1992) in which learning is based on the learners' interest and purpose. As the information space increases, with subsequent growth of links, there needs to be a balance between providing flexibility and ease of access, with the threat of being confused and overwhelmed by the selection of possible hypertext paths. A major aim of hypertext designers is therefore to find a balance between increased flexibility in the hypertext system, in relation to difficulties that users will face when navigating through the domain.

Adaptive Hypertext Systems (AHS) form a relatively recent research approach, examining the implications of integrating two distinct technologies in computer assisted instruction, that of Intelligent Tutoring Systems (ITS) and hypertext systems when browsing the information space. Integrating the two technologies (Duchastel, 1991; Jonassen & Wang, 1993; Costa Pereria et al, 1991) is in effect a combination of two opposed approaches to computer assisted learning: the more directive tutor-centred style of the traditional AI based systems, and the flexible student-centred
browsing approach of hypertext. The aim of the AHS approach is to provide support when the user is navigating through the hyperdocument.

There are three issues which have particular relevance for this thesis: (1) is adaptivity needed? (2) what types of intelligent tutoring elements can be added? and (3) what types of adaptivity can take place? This area of research on adaptive hypertext can highlight the problems of using hypertext for learning on the Internet, and also offers some suggestions for system design that could be incorporated into the guided discovery hypertext environment used in this project.

There are two reasons for providing adaptivity in a hypertext environment for learning. The first reason is that learners are not all the same. They may approach the same system with different learning styles, motivation, background experience and educational goals. In a conventional, static hypertext system the same nodes and links are provided for the learner, irrespective of individualistic differences. Therefore there is the requirement for a user model; a history of each learner which the system can use to make inferences about behaviours and goals to provide feedback based on the supposition that users may have different requirements when using the system. Secondly, adaptivity may alleviate the "lost in hyperspace" (Conklin, 1987) that learners have reported experiencing (La Passardiere and Du Fresne, 1992). Reducing the amount of available links open to selection will in turn reduce the navigational pathways that the user can take. Therefore sections of relevant material could be highlighted in terms of advice or visual indication. These two reasons reflect the approaches to adaptivity advocated by the AHS approach; that of adaptive navigational support and adaptive presentation (Eklund, Brusilovsky and Schwartz, 1997).

7.5.1 Methods and Techniques for Navigational Support

There are two main categories of features which can be dynamically altered in an adaptive hypertext system: presentation and navigational support. These can support the learner using different methods of adaptation.
Adaptive presentation operates at the content-level of the hypertext. The information contained in the hypermedia nodes or web pages is presented in an adaptive fashion by varying the detail, explanation, or media used; and to incorporate more or less link-anchors/hotspots in the hypertext. Most current work in this category focuses on text adaptation. This style of adaptation addresses the problem of a hypertext system being used by different classes of users by changing information presentation.

One method of achieving this is through limiting the browsing space according to different needs, background knowledge, interaction style and cognitive characteristics (Recker et al, 1995). The drawback with such adaptive presentation systems is that the adaptivity is based on underlying assumptions about the user, such as a model that assumes that a node will be visited frequently because it is relevant, but there may be other reasons why some nodes are visited more often (Eklund, 1996).

The second category of adaptation is adaptive navigational support which operates at the link-level. In this mode, the space of possible paths which can be followed by users may be tailored. This style of adaptation would address the problem of users being lost in hyperspace, by providing guidance and orientation support. Adaptive navigation support techniques can be classified into several groups according to the way they adapt the presentation of links using: direct guidance, sorting, hiding, and annotation (Brusilovsky, 1996). These will be briefly described, to suggest possible ways that a system can adapt or carry out guidance during the learning process.

Direct guidance is used in any system which is able to decide the next "best" node for the user to visit, according to learner goals and other parameters represented in the user model. A current example of this is the ELM-ART system which is accessible from the WWW (Schwarz, Brusilovsky and Weber, 1996). ELM-ART generates an additional dynamic link, called "next", which allows access to the next most relevant node to visit. Direct guidance has been criticised for being "too directive" as it provides almost no support for users who would like to make their own choice rather than follow the system's suggestion.

In adaptive ordering technology the links of a particular page are sorted according to the user-model, using some easily recognisable means of displaying this in the
interface. The way this has been done has been to have more relevant links closer to the top of the hyperdocument. This facility is available in ELM-ART and Interbook (Eklund, Brusilovsky and Schwarz, 1997). Adaptive ordering has limited applicability as it can be used only with non-contextual links. It cannot be used for contextual links and maps, or for indexes and content pages (which commonly have a stable order of links).

Hiding is an annotation technology which restricts the navigation space by hiding links to irrelevant pages. A page can be considered as irrelevant for several reasons such as not being related to the user's current goal or if it presents materials which the user is not yet prepared to understand (Brusilovsky, and Pesin, 1995; Vassileva, 1996).

The fourth type of adaptive navigational support is annotation technology. This augments the links with a comment which informs the user about the current state of the nodes behind the annotated links (Schwarz, Brusilovsky and Weber, 1996; de La Passardiere and Dufresne, 1992). Link annotations can be provided in textual form or in the form of visual cues such as different icons, colours and font sizes. Adaptive navigation support can be provided by dynamic user model-driven annotation. It can take a simple history-based form with an outline of the previously visited links, and is already included in several Internet browsers.

It should be noted however that those two styles of adaptation, presentation and adaptive support are closely related. For example the user can select a more detailed explanation by expanding the text on the current page or by adding more in-depth links.

Adaptive interfaces (Pitz, 1994) are a further combination of the two categories, where the appearance and form of the page and the navigational devices available change with the user's knowledge or tasks; affecting the content that can be viewed. This customisation of user interfaces has in some cases improved system usability (Benyon, 1993). There will now follow a consideration of the possible applications for navigation support on the WWW, which appear to be a prerequisite for successful learning.
7.5.2 Graphical Hypertext Navigational Tools to Support Learning

Although the creation and widespread popularity of the WWW is undoubtedly an advantage in the sheer amount of educational material that the learner can access; WWW technologies are regarded as lacking most of the functionality required for large, interactive and adaptive applications (Andrews et al., 1994).

When exploring a large corpus of knowledge, the difficulty is in the enormous amount of information that the learner may have to browse. The process of jumping from one location to the next can easily confuse the learner. This is primarily due to the user's lack of knowledge of the information space. Structuring large amounts of data using only hyperlinks to alleviate the feeling of being "lost in hyperspace" is difficult. WWW databases are large, flat networks of chunks of data, making it difficult to search for the relevant information.

Because students usually have specific educational objectives for a particular session this can come in to conflict with the possibilities for open-ended exploration presented by the Web. Novice users often feel lost in the information spaces, unsure of where they are:

"there is a risk that they will become disoriented or have trouble finding the information they need" (Nielsen 1990).

To fully exploit the WWW as a vehicle for the delivery of courseware a more supportive learning environment is required which can continue to make use of all the power of the Web whilst still maintaining a level of control over navigation. There is a need to provide navigational mechanisms that allow students to follow interesting links to resources anywhere on the Web; but also to return to the originating link to re-start the search for the current educational objective. Visualisation of the information space can help to alleviate cognitive overload and there have been two approaches to doing this. The first is the generation of overview maps that purely
help in an orientational sense to help the user gain an overview of the domain. The second is the inclusion of maps to help navigate the user forward in the exploratory process, and to provide functionality for re-tracing steps. This also has the added advantage of being able to structure and guide the learning process. There will now be a discussion of the value of adding maps for navigation, as they are included in the guided discovery and map only condition.

One of the major problems with current hypermedia systems is being lost in hyperspace. For example when using an Internet browser, the process of jumping from one location to another can easily confuse the user. This is primarily a result of the user's lack of knowledge of the overall structure of the information space. For this purpose overview diagrams or navigational views may overcome this problem. By presenting a map of the underlying information space, they allow the user to see where they are, what other information is available and how to access the other information.

Mukherjea and Foley (1995) suggested that when designing overview maps for WWW navigation, attention must be paid to the size of the underlying information space. As the overview map increases, it becomes very difficult to fit the whole information structure on a screen. The goal should be to display both the details and the context integrated into a single screen. If the size is reduced to fit on the screen, the details become too small to be seen. An alternative is to browse the large layout by scrolling and arc traversing, but this tends to obscure the global structure.

A large map can be useless if the overview diagram is too detailed or the window too small. Depicting all the interconnections between the nodes may make the structure overly complex; yet there should be details about node and link characteristics. To overcome this problem, Mukherjea and Foley have advocated strategies which use a combination of structural and content analysis of the underlying information space. Four strategies are applied to form the map views: binding, clustering, filtering and hierarchisation. Using abstractions, created by clustering, the user can view the overall information space without cluttering the view and keep the map on one screen.
With the actual graphical visualisation of the map itself, just displaying the structure of the hypertext is not enough for supporting navigation. To be really useful, the user should be able to get an idea of the actual contents of the nodes and links just by looking at the navigational views. The user can then base a decision on which part of the overall information space is of interest. For example, in the WWW, a user should be able to get an idea about the topic of the web page by the depiction in the overview diagram. Similarly, if certain nodes are important (such as landmarks), they should be identifiable from the views. To achieve this purpose, visual properties can be used in the overview diagram to represent information from the underlying information space. For example, the topic of the nodes may be represented by different colours. Similarly, special icons or brighter colours can be used to represent the landmark nodes.

These “attention-focusing” methods (Merrill and Tennyson, 1977) have been incorporated into the concept maps used in this experiment as a marker to show the learner where they are in the hypertext and also to suggest to them which concept is important, and is contained in the material at that particular stage. In terms of the size of the concept maps, these only show localised views of a specific chapter rather than the whole view of the domain, hence reducing the amount of concepts that need to be displayed at any one time. The linking is also labelled, giving the learner information of what each node contains and how it is interconnected to other nodes. This is discussed further in chapter 8 on the design aspects of the system used in the experiment.

The suggestion is that just providing a map depicting the information domain is not sufficient; and this seems to be the case for learning. To fully exploit the Web as a vehicle for the delivery of courseware a more supportive learning environment is required which can still make use of all the power of the Web whilst still maintaining a level of control over navigation. Guided tours are a navigational mechanism that allows students to follow links to resources anywhere on the Web.

In other hypertext systems guided tour facilities and trails have been used to aid novice users navigating through information spaces (Trigg 1988; Bush, 1967). They also provide a means of returning to the initial point where the student had left the set.
of materials associated with the current educational goal (Nicol, Smeaton and Slater, 1995). The advantages are that users can follow a linear path through a large information space, but they are still allowed to digress from the tour to explore other information sources with the ability to easily return back to the tour. Nielsen (1990) views guided tours and index overview features as able to foster exploration by providing a:

"wider coverage of the materials and more efficient access to new information".

The criticism of guided tours is that the concept actually defeats the strength of hypertext, in that it reinforces an emphasis on linear "page turning" rather than the free exploration of large information spaces. But the opposing view is that the learner is only relinquishing control over the exploratory process when the learner feels like there is a need to. The two areas discussed so far, overview diagrams and guided tours, lack the degree of adaptivity that some claim is required to support WWW navigation (Brusilovsky, Schwartz and Weber, 1996). A passive information source, even in the form of carefully sequenced web documents, can cause disorientation. The user may know how to get back to where they want to be by using the navigational tools that the Internet browser provides. Rather the problem is caused by information overload and distraction on the WWW that causes the learner to lose focus of their original goals. So an overview map can provide information about the structure of the domain, but there is a requirement for greater guidance according to specific educational objectives. Knowledge based navigation support could provide some of this guidance.

The overview map can be seen as being a "glass-box" model of individual student knowledge of the hypertext domain, showing to the student how learning is progressing and what the system understands about that progress. This is similar to ELM-ART (Brusilovsky, Schwartz and Weber, 1996) for supporting a knowledge-based approach to navigation. Once the student has visited a node it is assumed that the student has read and understood the material at that node. Therefore ELM-ART uses the assumption that the learners are purposeful and deliberate about their navigation through the hyperspace. It does not account for user behaviours such as looking ahead at material before reading it, or not understanding read material.
This knowledge based system approach to mapping, is more sophisticated than the concept map included in the system for this project. The cognitive mapping tool is not generated as the learner moves through the hypertext. Instead it is created to reflect each particular concept in a particular page (or 'chunk' of hypertext) and how it relates to its immediate other nodes. It is suggested that if it is combined with a tutorial component, it will be sufficiently well structured to support both the navigational process and to structure the understanding of the relevant concepts. Such a map would reflect the important concepts that need to be understood and how the concepts are inter-related without the need for the user modelling and generative processing that other systems that support navigational processes require.

7.6 The Merging of ITS and WWW Hypertext Environments

History-based adaptive annotation is a simple adaptation mechanism familiar to WWW users. Any WWW browser highlights the links to previously visited nodes, usually as different colours, to allow readers to distinguish between which parts of the hyperdocument have not been explored. This simplest form of annotation appears to be beneficial during navigation. The general idea of individualised annotation is to augment the links with some form of comments which can tell the user something about the document behind the link related to the current task. Annotations can be provided in textual form or as visual cues (Brusilovsky, 1994).

There will be a discussion of more advanced methods of adaptive annotation which may be supportive to WWW users. Some of these are implemented on the system used in this thesis, hence the need for a discussion of these issues. Three issues need to be considered when using adaptive navigation support methods: domain knowledge, the course itself and the characteristics of the student learner.

The domain model provides a structure for the representation of the user's knowledge of the subject. The simplest form of domain model is just a set of domain concepts. These concepts are named differently in different systems, such as topics, attributes,
knowledge elements and learning outcomes. But are essentially elementary pieces of knowledge for a given domain. A more advanced form of domain model is a network with nodes corresponding to domain concepts, with links reflecting several kinds of relationships between concepts. This network represents the structure of the domain in a hypertext system.

The individual user-knowledge model, the overlay model, is often used in adaptive hypermedia systems. An overlay model of user knowledge can be represented as a set of pairs of "concept - value", one pair to represent each domain concept. The advantages are that the overlay model is powerful and flexible because it can measure independently the learner’s knowledge of different topics. In relation to the domain model concept, an individual user knowledge model stores a value. The value acts as an estimation of the learner knowledge level of this concept. This take several forms such as a binary value, a qualitative value (good-average-poor), or a quantitative value such as the probability that the user knows the concept. For a discussion of user modelling and its contrasting approaches, chapter 8 provides a fuller discussion.

The knowledge about the course is represented by indexing hypertext nodes containing various units of learning material. The learning material can comprise of presentations, tests, examples and problem-solving tasks. This is a popular direction for the development of education-oriented hypertext systems.

In the design of the hypertext structure, there are two major types of indexing which the learner can access: content-based indexing and prerequisite-based indexing. With content-based indexing, a concept is included in a page index if some part of the page presents the piece of knowledge designated by the concept. With prerequisite-based indexing, a concept is included in a page index if a student has to know this concept to understand the content of the page (Schwarz, Brusilovsky and Weber, 1996).

Adaptive navigation can also be provided by using two other methods for hypertext systems on WWW: "knowledge-based" annotation and prerequisite-based annotation. The idea of the knowledge-based method is to distinguish different levels of the user’s knowledge of the node. This can take the form of three graduations: “not-known”, “partially known” and “well-learned”. The definition of "not-known" is that the user
has never heard about some of the concepts linked to a particular node. "Partially known" means that the user has acquired some information about all the concepts presented in the node, "Well-known" suggests that the user provided confirmation of knowledge of all the concepts presented in the node by answering tests or solving problems. The links to the nodes of these three classes are annotated differently to reflect these different levels of knowledge (de La Passardiere and Dufresne, 1992). This method requires a user model which is able to distinguish between the different levels of user knowledge of the concept.

The use of testing, to ascertain learner knowledge, has been used in the guided discovery system in this project. The subjects were pre-tested; ensuring a similar starting point in terms of knowledge for all the subjects. Continual assessment of knowledge was carried out by online testing carried out during the learning session, and analysis of navigational logs to establish the level of the learner's knowledge.

The "prerequisite-based" method categorises nodes as ready and not-ready to be learned (Brusilovsky and Pesin, 1995). The node is considered as not ready to be learned if any of the concepts in the prerequisite section of the node index are not-known. This method could be implemented using the simplest form of overlay model which only distinguishes known from not-known. Pre-requisite based adaptive annotation is a feature of the tutorial component in the guided discovery condition in this project, whereby learners are interrupted in their selection of links if they have missed out specific parts of the material or have shown inadequate understanding of the material that they have encountered. This is discussed further in the next chapter, chapter 8, on the design of the guided discovery learning environment.

To provide adaptation in a WWW hypertext system, there is a requirement for a measurement of user behaviour when using the system. Adaptive hypertext advocates the use of externally structured systems which are explicitly based on hypertext (or hypermedia), and use a model of the user's knowledge or goals to modify links or content to present individualised instruction or guidance. Therefore there will be an examination of user modelling to determine how this could be carried out for an adaptive hypertext system for the WWW.
7.6.1 The User Model for Creating Individualised Instruction

A user model in a hypertext learning environment is given less emphasis than in a traditional ITS. There is less of a need to constrict the learner during the exploratory process, with a shifting of emphasis on student-directed and guided learning. But this is counterbalanced by a requirement for greater support when learning from hypertext WWW systems. Individualising information and link-anchors (adaptive presentation) or providing the user with navigational support (adaptive navigation) is based on information kept in a user-model. This is the system's representation of the user's preferences, knowledge, beliefs, or information seeking goals. An example is the ISIS-Tutor, a hypertext-based system for teaching aspects of programming language (Brusilovsky & Pesin, 1995). The system was able to provide adaptive navigational support based on whether a particular student had selected a node which was already learned, ready to be learned, or not learned at all.

Different techniques have been used to acquire information about the user (Kobsa, 1994). These include stereotypes of learners selected by the system and user-supplied preferences at run time. Other methods have been an analysis of user actions and plan recognition or inference. Navigation between pages, methods of selecting the page, or explicit selection of tasks (Hook et al, 1995) have been used by the system in order to build a student model for carrying out inferencing of the user's intentions. The effectiveness of some of these techniques remains controversial. Kay notes that:

"Modelling cannot be anything but a guess if it attempts to model the user's knowledge" (1994).

Others researchers find commonality with this viewpoint, advocating a "glass box" approach, in that a user model should be inspectable by users and should work under their control (Hook et al, 1995). The suggestion is that the learners themselves already know their level of knowledge and personal preferences; such as preferred learning tasks to suit particular styles. Hence the learner should input or modify the
user model accordingly. This has itself come under criticism, as most user modelling systems are necessarily complex because they are written in AI languages which users would not know how to modify.

The user model used in this project is the overlay model, with a fairly simplistic structure. It is not as complex as other user modelling techniques that provide more detailed analysis; but the approach is powerful enough for the closed corpus hypertext environment that is used in this project (see the next chapter, chapter 8). An overlay model is used to adapt the level of guidance that the learner receives in the guided discovery condition. There are many intelligent and adaptive systems that rely heavily on user modelling techniques. Knowledge representation can take many diverse forms: such as scripts, stereotypes, statistically-derived schemes and propositional approaches. These are complex in comparison to the approach used in this thesis. By constraining the method of interaction between the learner and the system, a minimal user model is effective (Taylor and Self, 1990) and is a factor for the success of some ITSs (McKendree, 1990).

In the closed corpus educational scenario the tutor has a significantly greater opportunity to obtain information about the user through testing. The hyperdocuments may be arranged in a hierarchy of interrelated concept nodes, each node consisting of multiple pages of material including explanations, remediation, extension, review and testing. Information gained from testing enhances the quality of the data held in the user model, supporting the ability to customise information or links. Hence the requirement for testing in all the experimental conditions of this project.

To determine other user-centred principles with which to design a navigational support system, knowledge of content and interface familiarity are seen as key components in determining the level of support that the learner requires. Linard & Zeiliger (1995) propose a three-phase model for educational software. This model begins with the learner working through an introduction, moving to a tutorial and finally free-browsing with adaptive navigational support. This is a teaching approach in which the learners increase their level of autonomy with time and experience, progressing to more active learning through orientation, coaching and tuning stages,
and is based on cognitive theory (Chan, 1993). These stages resemble some of the stages in a decreasingly interventionist approach to tutoring, part of the guided discovery pedagogy for learning advocated by this thesis.

7.6.2 Coupling ITS, Hypertext and the WWW

A possible method of incorporating ITS functionality to WWW is to port specific ITS technologies to WWW. In terms of learning, the most relevant technique to support learning is intelligent knowledge sequencing and problem sequencing. Intelligent knowledge sequencing adaptively selects the next topic to be learned based on the student model and knowledge about the learning material. Intelligent problem sequencing is composed of selecting or generating the next problem for the student to solve. The problem that is set should be relevant to the level of knowledge and skills of the learner. This can be applied to all types of teaching material, with adaptive sequencing of examples, tests, problems, and questions.

Implementation of intelligent sequencing within a hypertext framework brings a combination of student-directed and guided learning. It can help to alleviate the "lost in hyperspace" problem (Conklin, 1987). Learners unsure of where they are, or where to go next can use system guided navigation. At the same time it provides benefits over traditional "directed" ITS styles of teaching. The combination of hypertext and ITS approaches can be used in the WWW so that students who are not satisfied with system-directed sequencing, can use a hypertext style of browsing of the learning material (Brusilovsky, 1995). It is this degree of control and the form that the guidance should take which is of interest in this project. The learner in the guided discovery system has a tutoring element that offers guidance; continually allowing the learner to browse the material and only intervening if it is determined that browsing is carried out in an ineffective manner in terms of sequencing. If there are any misconceptions the learner is taken through lower levels of the hypertext, containing different system advice, to help them approach the concepts using a guided discovery episode (see chapter 8). Therefore support is given both at the node level, with specific advice, and at the structural level with concept maps and general navigational advice.
In terms of the problem of information overload, there have been steps to provide the learner with individualised help (Espinoza and Hook, 1996). The PUSH (Plan and User Sensitive Help) system was able to generate Web pages dynamically making the Web more interactive as a learning medium. The system utilises the user's information seeking task for carrying out an adaptive filtering mechanism. The PUSH system is a platform independent, interactive, adaptive system for filtered information retrieval on the Web. The knowledge database and the interface are separated in the architecture, with the student model being derived from the information seeking tasks of the user.

Hypertext able to provide individualised instruction on the WWW remains at a preliminary stage. Interest has grown with Adaptive Hypertext systems research but there are no established frameworks for the design of such hypertext systems. The research outlined in this project will contribute to providing principles for guidance in the design of these environments for learning. The web material in the guided discovery system used in this experiment was not dynamically generated, but the advice was adapted to aid in overcoming specific misconceptions and also for supporting navigation in a closed corpus scenario.

It is suggested that in future technologies, an Intelligent Agent would follow the learner when navigating in an open corpus web space. Because these users would most likely require less-specific information, an Intelligent Agent could be used to suggest at each step which of the links to follow. Once the learner customises the agent with personal preferences, it may be able to inform the learner about specific information, accompanying the learner ‘surfing’ the web, highlighting hyperlinks that it believes will be of interest. Its strategy for giving advice is gained from feedback from earlier tours, drawing on individual histories of the learner. This area of research is also in its infancy.
7.7 Summary

There are many possibilities in the applicability of adaptive navigational systems to the Web. Viewing educational hypertext systems as categories of closed and open corpuses of information can aid in the design of learning systems as they are based on different learner requirements. For closed systems, the Web component (residing on the server) may either be a generated HTML interface between the student and courseware which provides a range of appropriate navigational tools, or a front-end to an adaptive information retrieval system. In the open-corpus scenario the educational goal tends to be on navigation and information retrieval on the Web. Providing an adaptive module such as, for example a Java applet residing on the client, may be able to record the users interests, frequency of visits to links, characteristic uses of navigational tools and information seeking tasks, and to adaptively annotate links (Eklund, 1995; Pang and Edmonds, 1997).

Some of the theoretical issues concerned with using hypertext web pages can be derived from work on hypertext, ITS and emerging applications of WWW technologies. Clearly there are multiple influences on the design and implementation of the adaptive systems. There are many areas that can contribute to learning and the WWW such as findings from: studies of educational pedagogy and their input into architectures for computer-based learning environments, learning and cognitive theory, instructional design principles, developments in software tools and methods, and empirical studies about the nature of the user and the effectiveness of the environment. A successful integration of a number of these areas is required to form guiding principles to inform the research area learning and the WWW.

The research in this thesis has focused on implementing components from some of these areas. The tutorial component is used to provide guidance in terms of navigation and understanding of the material, a concept mapping tool to focus attention and to orientate the learner; and a guided discovery pedagogy to maintain a deeper cognitive level of processing.
Questions could centre on: why use the web for learning? The literature has shown that the WWW remains unexplored for distance learning providing many alternate modes of interaction in the educational material. In its most basic functions, it offers a vast repository of educational literature (and more recently as a tool for collaboration) hence it has begun to be used more widely in classrooms in the UK. But as the lack of established data on its effectiveness shows, its full value as a teaching medium for individual instruction has yet to be realised. Kay and Kummerfield (1994) predict that:

"Hypertext Systems such as the World Wide Web hold great promise as a vehicle for delivering self-paced instructional material".

The web's initial attraction came from the use of hypertext based applications that provided a graphical user interface in which to navigate the Internet hyperspace. Incorporating an intelligence dimension into the web: that of the ability to "understand" the user, to customise information and presentation and to dynamically support navigation; may create the functionality that is needed to make the web into a valuable teaching mechanism rather than as a way to access information.

It is proposed in this thesis that there is a need for a guidance mechanism to be incorporated into the hypertext learning environment in order to support learning from the Web. There is a need to control the navigational process in hypertext, and limited navigational tools may place an additional cognitive load on the learner. The learner is typically left to explore the material which is not structured according to any instructional design model. There remains a paucity of research and evaluation into the WWW and hypertext as a viable tool for educational purposes, and (in the case of this project) for individual instruction. Therefore it remains clear that there is a need for research into the pedagogical value of current materials placed onto the WWW which are purported to promote learning.
8.1 Introduction

A framework has been discussed for the categorisation of various types of teaching style in chapter 4. The framework discussed in chapter 4 highlighted the components that comprised the different pedagogical approaches related to teaching styles. This frame of reference will be used to explain the design of an instructional system for the WWW.

Previously a discussion of guided discovery has taken place in a human teacher-learner situation. The role of the human teacher is to determine the relevant material, the questions to pose, the design of the discovery sequence and feedback for the learner. The learner plays an active part in working through the sequence and acting on the feedback, but not participating in the creation of the learning material.

It needs to be recognised that guided discovery is one style of teaching structured to accomplish a particular set of objectives whereas other styles will accomplish different goals. The reason for selecting this particular teaching style is because of the contradiction between the exploratory nature of hypertext (in the form of web pages), and the need to impose structure and guidance on the learner as they navigate the hypertext. It is argued in this study that guided discovery is a suitable educational paradigm for this type of learning medium.
8.2 Extending the Framework of Teaching

To determine the design of a Guided Discovery Hypertext Learning Environment for the WWW, the analysis of teaching styles in the form of a spectrum (Mosston and Ashworth, 1994) was used. This acts as the framework for the design of the guided discovery condition in this project, determining when guidance would occur and the form that this would take. If a similar schematic representation is used, the guided discovery system can be illustrated according to where it lies within this framework. Figure 13 (overleaf) displays the anatomy of the guided discovery teaching style (modified from Mosston and Ashworth, 1990)

The stages of decisions made about the different components of this teaching style are shown as six interrelated areas: (1) axiom, (2) anatomy of the style, (3) decision-making, (4) spectrum of teaching styles, (5) clusters and (6) developmental effects. Particular characteristics of the system used in the guided discovery condition are what differentiates this from conventional hypertext systems currently prevalent on the WWW (Edmonds and Pang, 1995). There are different considerations in the preimpact, impact and postimpact phases of the learning episode. Illustrated in the decision-making sector of the figure are the varying levels of control (during the learning process) that both the teacher and the pupil have. The decreasing interventionist strategy used in the system means that the system will always retain some level of control. Guided discovery is denoted as style ‘P’ in the spectrum of teaching styles. Emotional and cognitive developmental effects are discussed in a later part of this chapter.

These will be discussed in specific relation to the design of the guided discovery system, and partly reflected in systems in the map and unguided conditions. The shaded parts depict the position of the system within this framework. The discussion in this chapter will use the structure in order to outline each component of the system and the role of the teacher-learner in the learning episode which is created by the design decisions.
1. The AXIOM:

TEACHING BEHAVIOR IS A CHAIN OF DECISION MAKING

2. The ANATOMY of any STYLE:

PREIMPACT

IMPACT

POSTIMPACT

sets of decisions that must be made

3. The DECISION MAKERS:

Teacher

maximum

minimum

Learner

minimum

maximum

4. The SPECTRUM:

A B C D E F G H I J K

5. The CLUSTERS:

6. The DEVELOPMENTAL EFFECTS:

Physical Developmental Channel

Social Developmental Channel

Emotional Developmental Channel

Cognitive Developmental Channel

Moral Developmental Channel

Shaded regions represent Instructional Design Consideration for a Guided Discovery System

Figure 13: The Anatomy of Guided Discovery as a Teaching Style (modified from Mosston and Ashworth, 1990)
The axiom is based on the initial premise that teaching behaviour is a process of decision-making; and this is maintained in the design of the guided discovery system. In the development of the experimental conditions every part of the teaching sequence has been tested. Learning sequences, system intervention and learning material have been formulated to lead the learner through a series of smaller discoveries accumulating in the discovery (understanding) of the target concept. In this case the teaching sequences are designed prior to the experiment, the material is constructed according to specific conceptual guidelines (see section 8.4.2); and educational goals for the particular teaching style are formulated. This educational pedagogy has been used as a deliberate approach to teaching, whereas other web-based teaching systems do not have such an overt approach to the design (Benyon, Stone and Woodriffe, 1997). These are discussed in detail in the sections that follow.

8.3 Implementing Guided discovery

To implement a teacher-learner process in the form of a computerised system there should be an examination of the anatomy of the teaching style. To establish how some of the characteristics of guided discovery teaching from a classroom scenario can be transferred to a distance learning scenario in an electronic medium. Mosston and Ashworth (1990) have used a model called the spectrum of teaching styles to divide each style of instruction into several sets. Decisions carried out for a teaching-learning episode comprise the anatomy of the style: the preimpact set, impact set and postimpact set. These will be used to explain the design of the guided discovery system used for this project.

8.3.1 The Preimpact Set

These are decisions primarily carried out by the teacher. The following decisions have to be taken:
The objective of the guided discovery condition is to teach a beginners level in electronic logic although it is equally as applicable to other educational domains (see chapter 11, Future work). The aim of each lesson is to discover specific concepts related to that particular lesson. Some of these concepts are tested by the system, while others which are not included are covered later in the paper exam. They are not tested in isolation, instead many of the problems require the learner to use knowledge of many interconnected concepts. The selection of the teaching style is the guided discovery approach. It has been discussed in relation to programmed instruction (chapter 2), the convergent discovery approach and also in computer-aided instruction (chapter 3). Part of the reason why it has been selected is that it is able to reflect the exploratory behaviour promoted by web browsing and also retains a structured approach to the exploratory process.

The anticipated learning style of the learner is variable, but can be subdivided into four learning styles as measured by the Learning Styles Questionnaire (Honey and Mumford, 1982): Activist, Theorist, Pragmatist and Reflector. The hypothesis in this thesis predicts that the majority of learners will find the guided discovery condition as favourable to use as the unguided condition. The system is able to give corrective instruction, thus the tasks that are given will support the preferences of the various learning styles to the same degree as the other experimental conditions (map condition, conventional hypertext).

In terms of who to teach, the subject population were undergraduate and postgraduate students who had experience of using the Internet but had not carried out modules in electronic logic. It could not be assumed that those in, for example, Information Technology had been formally taught electronic logic as these were not compulsory
subjects. The subjects also had to display a willingness to learn this particular topic when provided with information about the experiment. Subjects were not told to just browse the topic, but were informed that they would receive a written exam at the end of the learning session and that online tests would be given in relation to topics in the written exam. In designing the guided discovery condition, decisions were made about the concept to be discovered, the sequence of steps (questions) and the size of these steps.

The primary part of the guided discovery system is in the:

- direction of the sequence of steps
- size of each step
- interrelationships of each step
- speed of the sequence of each step

To convert the material into concepts the approach by Merrill and Tennyson (1977) was used both for formulating the size of the steps and determining navigational control by the system (discussed in section 8.4.2). The conceptual model created by using this instructional design approach has been used to break down the material and to formulate the size of the steps required to understand a particular concept. To create an internal connection between steps related to the structure of the subject matter, concept maps were used to display how the nodes (concepts) were linked in the hypertext space. It was predicted that this would support progression through the steps.

Each discovery step was tested and proven as the most efficient at that particular point in the sequence. For example if the learner did not understand a particular concept, in order to design related steps to bridge this conceptual gap, the system designer needs to be able to anticipate the possible responses that the learner will give to the question or clue. The steps which follow lead to the convergent discovery of the desired concept. In guided discovery the onus is on the teacher to precisely design questions which will elicit the correct responses. In some respects the performance of the learner is directly related to the performance of the teacher.
There are two types of guidance which have been designed for the guided discovery condition: Navigational guidance and Learning material guidance. Navigational guidance is concerned with ensuring optimal navigational behaviour and sequential coverage of essential material. Learning material guidance is subdivided into three levels: guidance that all users receive (first level), guidance concerning a specific concept (second level) and guidance concerning the same concept but at a different level of explanation (Third level). This extends the step structure put forward by Mosston and Ashworth (1994) as they do not propose such small levels of steps which lead to smaller conceptual ‘leaps’. Learning material guidance is discussed in detail as it is partly where, this thesis argues, the power of the guided discovery approach lies in bringing guidance and discovery together.

If the learner works through specific material following pre-specified steps, it is not guaranteed that they will discover or understand the relevant concept. An incorrect answer is evidence that the learner has been diverted tangentially, experiencing difficulty following the sequence of guided discovery steps. The step from the previous question is conceptually too large to be bridged. Learning material guidance will allow the learner to overcome this conceptual gap between what is known and what is unknown, hence reducing the required conceptual leap. If after first level guidance the learner is still unable to understand the material, the system will signal to the learner the principle that is causing difficulty (based on the incorrect answers given during the online testing). The learner can then return to the contents web page. At this point there are two choices open, to “carry on” with the next lesson or to “withdraw” from this sequence and to work through the second level of guidance.

If second level guidance is selected, the steps for the discovery are divided into smaller steps. The user will work through these steps and again return to the contents page. If the learner still has difficulty in understanding the particular principle, then they are given the option of a third level of learning material guidance. This third level reduces the cognitive steps even more, taking the learner through each specific part of the concept and eventually summarising in basic form what the answer is. The advice used to support this guidance process is discussed in section 8.4.3. The main
premise is that the advice, often in the form of questions, will focus the learner on aspects of the concept which will allow understanding.

The ratio of steps is variable depending on the background of the learner and the material being taught, but it is suggested that there needs to be many more levels of guidance steps in the sequences of domain material. Figure 14 (overleaf) depicts this increasing ratio of guided discovery steps to support learning.

The example used to illustrate how the guidance steps operate, is the lesson given on minterms in the lesson entitled "Problems of more than Two Inputs" (lesson 6). When describing this as a Stimulus-Dissonance-Mediation-Response (S-D-M-R) process, the lesson material acts as a stimulus for creating a level of cognitive dissonance. In a sequence whereby the subject experiences no problems, an ideal learning sequence of discovery is one where:

- The learner works through the sequence (mediation phase) with no misconceptions or difficulties in understanding a particular concept.
- Will read the guidance advice, which appears alongside particular points in the material to aid understanding.
- The learner will continue to carry on climbing the steps eventually discovering the desired concept (response).

Therefore learning material guidance will only be activated if there is failure in the online exams (given at the end of each lesson).

If the subject fails the online testing, it will be assumed that there are difficulties in understanding a particular concept or principle. Immediate feedback following on from the exams will begin the secondary phase of the guidance (Guided discovery level 2). The learner will be informed that the concept of minterms has been misunderstood and receive recommendations of relevant new areas of hypertext material that have been opened. The learner will return to the contents page and further advice will inform the learner of the specific new links for helping to understand minterms.
Figure 14: An Extension of Mosston and Ashworth's (1990) Guided Discovery Steps
If for example the learners fail the online test in lesson 6 (Problems with More than Two Inputs) and selects the link on “Further Explanation of How to derive Minterms”, they will:

- Be taken to a sequence of steps guiding them through a different approach to understanding the same concept.
- They have to complete the full sequence of steps (as navigation control is removed from the learner) whereupon they reach the conceptual subgoal.
- After completion, the learner will be brought back to the contents page.

If there is a third level of guidance for the topic, the learner has the option of selecting it and working through this sequence (level 3 guided discovery). In this example, the third guidance level is a step-by-step explanation of the Minterms process. The assumption is that learners need different levels of explanation.

To provide an over-simplistic explanation may treat the learner as inferior, while making the explanation more difficult will allow the learner to be cognitively engaged in trying to understand the concept. Being told the answer is not as powerful as discovering the answer by actively discovering the solution (Bruner, 1966). The most simplistic explanation is found at the third level of guidance whereby the learner is told the answer as the last step, rather than just using a series of questions. This simplistic step is often the longest as it involves a breakdown of the material to be learnt into the smallest conceptual ‘chunks’ of information possible.

Mosston and Ashworth have also identified the designing of the steps, with additional steps being seen as an essential part of the construction of a guided discovery teaching episode. There is little research on how these steps should be constructed, nor are there established guidelines for the form that any advice should take in these smaller discovery steps, or even the amount of steps needed. It is the aim of this research to explore the value of including several levels of guidance and the form that this should take.
The learner is free to ignore the advice to explore these lower guided discovery steps, so the learner continues to maintain a high degree of freedom during the exploratory process. Therefore the guided discovery steps proposed in this thesis could be viewed as being elongated and further dissolved into smaller steps requiring less of a cognitive leap. The learner will continue to follow a Stimulus-Dissonance-Mediation-Response (S-D-M-R) process, whereby every step will lead to the use of cognitive skills apart from just recall. The additional guidance steps can provide cognitive support by providing a rigid sequencing of material with particular advice. Those who have no difficulty with the discovery sequence are given the option of these lower levels of guidance but they receive specific advice that they do not need to follow them. This will reduce the cognitive overload on the learner in having to decide which part of the hypertext space to explore next.

Another view of the additional guided discovery steps are to see this as providing additional cognitive scaffolding in supporting the learner during domain exploration. The discovery steps put forward by Mosston and Ashworth are judged as not providing enough support to those who may face real difficulty in understanding the concepts and principles in the material. The value of these steps can be measured in this project by the amount of learners who decide to take these further secondary and third levels of guidance. The more users who take these steps (when they have failed parts of the online exam) the greater the perception that these levels are of use in aiding understanding. Not all concepts have a third guidance phase, only those concepts that have been identified as particularly difficult to understand have this third sequence of guided discovery steps. Therefore in the guided discovery system built for this project, there is: (1) control over the size of each of the steps, (2) advice (coupled with the concept map) to allow the learner to understand the interrelationship between the steps, (3) the speed of the sequence is controlled fully by the learner (to cope with differing speeds in learning and browser delays), and (4) system navigational control for sequencing material presentation.

It is suggested that this particular approach to providing guidance within the learning material, coupled with navigational control, will provide greater support for learning in a hypertext environment. To support understanding, the use of a conceptual map will aid in the understanding of information given at all the guidance levels. The
learner, when taken to these lower levels will continue to be shown how these concepts are inter-related to aid understanding (which will be less likely to be lost when returning to the contents page).

8.3.2 The Impact Set

After determining the sequencing of the questions, during the learning process the guided discovery system has to allow a certain amount of time to wait for the learner's response. The main characteristics of the teachers' role are outlined by Mosston and Ashworth (chapter 4) and have been replicated in the guided discovery condition using system control. These are re-iterated below:

- Never tell the answer.
- Always wait for the learner's response.
- Provide frequent feedback.
- Create and continue a climate of acceptance and patience.
- Support the emotions of the learner

The requirement to never tell the answer is enforced throughout the sequence of questions when the learner follows the ideal path of discovery, progressing through each of the steps. This principle is not adhered to when the learner requires the third level of guidance (level 3). It is suggested that it is better to tell the learner the answer than not to discover the answer at all. If they have selected this level, it is suggested that reducing the steps even further and eventually telling the answer may help the learner to grasp some understanding of the target concept.

Frequent feedback is given by the system in terms of navigational guidance, online testing and level one guidance during learning of the material. The learner is given acknowledgement that the correct target has been discovered through the system response to the online testing. System response has been pilot tested so that it is not perceived as condescending, but to be productive in suggesting to the learner other parts of the material to explore that may aid understanding. The learner should perceive the feedback as encouraging or explanatory even if the answer given was
incorrect. An example is the following segment of advice for understanding Logic Gates, displaying the message “Don’t worry if you don’t understand the concept at the moment. It will be explained in more detail in the next section”. The suggestion is that the learner proceeds with exploring the next step in the discovery sequence as this may clarify the information. Hence this may motivate the student to continue to explore the material.

The role of the learner is to follow the question, exploring the clues that are given about how to understand the material. To actively explore the hyperdocuments in order to find a solution to the question posed. This is supported by periodic system feedback to guide the discovery process. The key to the guided discovery approach suggested in this thesis, is that the sequence of steps and the advice that are attached to this are structured for different levels of understanding and, that encouraging the learner to discover is the key to learning. By following the questioning, or exploring specific statements given by the system, the cognitive engagement that the learner experiences with the material is increased.

8.3.3 The Postimpact Set

Mosston and Ashworth (1990, 1994) suggest that the teacher should provide frequent feedback in this postimpact phase. Feedback is built into every step of the impact phase and it also continues to appear in this phase. It is suggested in this thesis that it is beneficial, in the Guided Discovery condition, to continue doing this throughout the learning episode. Both the impact set and postimpact sets should provide reassurance to the learner that the answer to each question is correct or that the discovery process is able to lead to the discovery of the target. It must be remembered that the experiment is to replicate a distance learning scenario, whereby there is no human teacher present to provide further explanations or encouragement. Therefore the feedback, unique to this particular teaching approach, should be integrated into the postimpact set. Positive feedback will encourage the discovery process to continue when the domain material may be completely unknown to the learner. If, during the process of guided discovery, the response of the learner is flawed, the system is able to provide:
• Smaller steps with increased guidance for the learner to grasp.

• Responses, often in the form of further questions concerned with asking the learner to focus on particular aspects of the concept. Or to approach the same material but to tackle it from another perspective. This allows the learner to fully understand the current stage before deciding to move on to the next stage.

System feedback and self-assessment built into the learning environment will allow the learner to gauge progress. In terms of the emotional threshold, in the Guided Discovery process the nature of the interaction should lead to a positive attitude towards this experimental condition. The learner is dependent on the selection of specific stimuli presented by the system. This means that the learner relinquishes control temporarily in determining what is to be learnt next, with the sequence being pre-specified by the designer when the learner selects a specific discovery sequence. This approach could be seen as constractive but it is suggested in this project that the guidance does not hinder the exploratory behaviour of the learner but instead reduces the possibility of being lost in hyperspace and increases the possibility of overcoming misconceptions.

The use of questioning and clues to shape the discovery process will allow the learner to become deeply engaged in the material. This will allow the learner to cross the discovery threshold, with cognitive development maximised by the learner being engaged in the active search for a solution. Following the sequence of questions will encourage the learners to be cognitively engaged with the material. If the steps and questions are not suitable for different learner characteristics (learning styles) then this will be reflected in lower exam scores and lower user satisfaction levels, related statistically to specific learning styles.

8.4 Designing Electronic Logic Material for Guided Discovery

Electronic Logic has been determined as the topic for investigating this particular approach to teaching, although other domain topics could be equally as suitable.
Categories such as concepts, principles, relationships and order are present in the material. A test was administered to determine possible candidates for the experiment. This was used to determine levels of previous knowledge on the topic. Those who were too familiar with the topic were rejected from participating. Therefore the topic or target was unknown, retaining the principle that the learner cannot discover something that is already known. This section will first give reasons for the suitability of Electronic Logic as a domain for investigating guided discovery. Secondly there will be a discussion of how the domain material was constructed for specifically supporting the teaching of concepts.

8.4.1 The Suitability of Electronic Logic as the Subject Domain

The domain selected for learning was Electronic Logic, with the guided discovery, map only condition and unguided condition containing the same hypertext domain material. The level of expertise of the material was introductory level in nature, with no previous knowledge of electronics or computing required. This level of electronic logic is taught in many undergraduate courses that have an electronic, computing or design element and provides an initial grounding from which to base more detailed understanding of principles of computer and electronic hardware.

The domain material was divided into a total of nine lessons:

- Introduction
- Logic Gates
- Boolean Logic
- Truth Tables
- Problems With Only One Input
- Problems With More Than Two Inputs
- Evaluating Logical Expressions with Unknown Compounds
- Evaluating Logical Expressions with Known Compounds
- Implementation using Gates.

The lessons on Logic Gates and Truth Tables were seen as providing the essential prerequisite knowledge for understanding the remaining lessons.
The learner would receive greater support, increased levels of guidance and more online testing, at the earlier stages to ensure a competent framework in which to situate the remaining concepts. Although subjects could decide to go on with the remaining lessons without prior understanding of previous chapters, the system would provide advice dissuading them from doing so. The material was subdivided into lessons according to the grouping of concepts. So for example, to understand truth tables the learner had to first work through the related concepts in the material on Boolean algebra. These would be grouped together to form hyperlinks for that specific subject area. An integral part of the material was the extensive usage of examples (as described in the instructional design section, section 8.4.2) as part of the discovery approach to learning. Some examples of the web material are included in appendix D, along with system advice specific to that learning stage in the material.

The electronic logic domain was deemed a suitable subject area for testing learning outcome because it contained a mixture of procedural and declarative knowledge. The procedural knowledge consisted of techniques used to analyse the operation of logic devices, applying knowledge about Boolean notation and subsequent functioning of logic gates to create logic circuits. The declarative knowledge consisted mainly of concepts involving electronic logic.

The aim of the study was to teach a subset of logic, as an example of a formal course that could possibly be found on the Internet although not to the depth of a full electronics course. The material was validated by two members of staff who taught Introductory modules on Logic at undergraduate level. This was to ascertain that the correct level and adequacy of material was covered. The transition from the paper-based version to hypertext WWW pages were also overseen by these lecturers. The pilot study would go on to confirm that there would not be too much or too little learning material available for an estimated one hour of continuous learning, according to different rates of learning. It was decided to include more material rather than less to account for possible differences in pace of learning, as the system would have no control over this factor. There were several factors which influenced the selection of Electronic Logic over other topic domains:
• The ability to apply these findings to teaching on the WWW. Electronic logic is a vehicle for testing guided discovery because any knowledge gains are measurable. The topic was deemed as unambiguous with no room for opinion, thus making it testable, not open to opinion or argument, and similar in some respects to other fact-based subject areas.

• The continuing requirement to teach this topic – electronic logic remains a prerequisite topic for undergraduate education in electronic or computer-based subject areas. Discussion with lecturers from related areas provoked interest in a web-based system, accessible via the university campus server both for distance learning and on-campus learning. The web material can alleviate the initial time taken to teach this essential subject, freeing the lecturer to teach more progressive material.

• The difficulty in grasping the concepts - electronic logic may seem a straightforward topic to teach, but lecturers who teach this topic continue to mention that students experience difficulty in grasping these topics when they are presented in lectures. It is suggested that placing this topic in a WWW learning environment using guided discovery may aid understanding. Placing the topics in a web-accessible form may also encourage learners to read the material after lectures.

• The lack of interactivity with other similar courses using network technologies - the university Distance Learning Research Group had built a Lotus Notes version to teach Electronic Logic to Managers on the MSc in Engineering course for the Ford Motor Company. Assessment of the actual system, discussion with the educational authors and an examination of some preliminary feedback suggested a lack of interactivity and instructional support by the educational system which a web-based system offering individualised feedback and instruction could possibly provide. Current WWW-based hypertext tutorials often resemble lecture notes but in HTML format, hence offering little support for learning (Chapter 6 on distance learning and the WWW discusses these drawbacks).

Therefore it was determined that there would be a need for such a course after the construction of the system, with a guided discovery learning environment providing the support that is needed for distance education demands.
8.4.2 Conceptual Design of the Domain Material

The conceptual design of the material is linked to the section, Concepts and Schemata (Section 5.9). The aim in the design of the material is to create hypertext divided into concepts that are inter-related, and which can be assimilated into existing knowledge structures that the learner already has. The aim in this thesis is to construct an educational hypertext system which can use various guidance techniques to encourage cognitive activity. Conventional hypertext is essentially a static passive medium (Laurillard, 1993; Landow, 1990). In order to be able to navigate the hypertext space and to integrate the information, the learner must be able to self-regulate the learning process, determining where to go and what to learn. This requires metacognitive strategies (i.e. learning how to learn from hypertext) which they usually would not possess. The hypothesis in this domain is that a minimalist interventionist strategy by the system is enough to support learning. This is also reinforced by smaller discovery steps to guide the learner when there are difficulties understanding the concepts. But it is also suggested that the design of the material should also follow instructional design techniques, that can specifically enhance conceptual understanding.

These design techniques sub-divide the material into concepts, which can be used to determine: (1) how the concept can be introduced, (2) the difficulty level of learning specific concepts, (3) the types of examples used to teach that concept, and (4) how to assess understanding of that concept. The instructional design guide by Merrill and Tennyson (1977) was used to structure the learning material. It was also used to help create the nodes and links of the concept maps and to assess when the learner would require most support from the system. This could be seen as a "recipe" for creating hypertext material based on cognitively efficient instructional guidelines, and partly as a basis for adapting the learning environment. A brief overview of the instructional design steps will be given to explain the design of the domain material.

Instructional design is used to refer to the selection and design of material to help students learn more effectively and efficiently. It also entails specific ways to teach a singular concept or a set of co-ordinate concepts. As mentioned in chapter 5.9, the definition of 'concept' is changeable depending on the context of its use. Concept in
this thesis is defined as a mental representation of a category (Howard, 1987). Novak and Gowin (1984) define concept as regularity in events or objects designated by some label. Merrill and Tennyson (1977) view a concept as a set of specific objects, symbols or events which are grouped together based on shared characteristics and which can be referenced by a name or symbol. What is pervasive in all these definitions is the emphasis on some identifiable similarity between a certain set of objects, that allow them to be placed into a category. They can therefore be referred to by a label and the learner will be aware of the similarities that the label will suggest. For example, the concept of an OR gate is placed under the category of 'Logic Gates'. Logic Gates as a label will suggest to the learner that the OR gate will have certain components, behaviours and applications. This classification behaviour is evidence that the learner has correctly identified the concept. The ability to discriminate between objects and to generalise from them is an integral part of the learning process, hence the advantage of designing material using a specific instructional design approach.

Merrill and Tennyson (1977) provide an 8 step process to designing material for concept learning. These are listed below:

Step 1 – Decide if a concept lesson is needed. This is determined by whether the learner has to “understand”, “know how to use” or “know the meaning of” a new term. Whenever the lesson material requires a definition or a principle then this can be done with a concept lesson. Electronic Logic requires the learner to know, understand and apply concepts and principles.

Step 2 – Define the Concept. Ensure that the material contains clear definitions of each concept, to allow the learner to understand how to use the concept for carrying out classification behaviour (generalisation and discrimination).

Step 3 – Collect an Instance pool. Select examples that display critical attributes of the concept.

Step 4 – Estimate difficulty for each instance. Some concepts are easier to classify than others. Instance difficulty is the probability of a given instance being classified
properly by a group of learners. Basically, to present the instance and determine how many learners categorise it correctly. This was carried out with the consultation of lecturers and in the pilot study phase.

Step 5 – Prepare a diagnostic classification test. The design of tests that allows the teacher (or researcher) to determine the student’s ability to classify newly encountered examples. This was carried out in the online testing, which presented questions that tested knowledge of concepts, and in the written exam administered after the learning session.

Step 6 – Prepare attribute isolation. The use of an attention-focusing device can direct the learner’s attention to critical attributes of the specific example. This was carried out in the guided discovery condition by the presentation of advice that specifically directed the learner to the concept or principle that needed to be understood. This was also strengthened by the use of colour (red font) to isolate the concept both in the material itself (see section 8.5.2 for design of the interface) and in the concept map (section 8.4.2 for concept map design).

At this stage of the instructional design, there should also be the determination of the primary presentation forms to be used in the material. Presentation forms can be in expository form (to tell) or in inquisitory form (to ask). The presentation can include a mix of rule, example, practice or recall; each asking the learner to carry out a specific task. A mixture of expository and inquisitory forms were used in the design of the learning material, where parts of the concepts were explained; whereas other parts were in the form of questions and subsequent explanation of the answers.

Step 7 – Design the instructional strategy. This is to decide whether to use certain presentation forms in a specific sequence. The most common approach used in this material was to present an example, present a rule, then follow this with an example, then provide practice. It should be recalled that guided discovery involves supporting the learner as the student proceeds through this process of working through the material.
At this stage there should also be the construction of a framework for how each of the concepts is co-ordinated. A superordinate concept can be divided into subordinate concepts. These subordinate concepts are called co-ordinate concepts. For example the concept NAND gate can be subdivided into subordinate concepts related to NOT and AND gates. These concepts become co-ordinate concepts. This was used to determine how nodes (concepts) can be linked and also for the construction of the concept maps.

Step 8 – Formative and summative evaluation. Formative evaluation is concerned with the material during development, summative evaluation determines the effectiveness of the material when it is being used. Evaluation of the material was carried out during the creation of the material and during the pilot study. In particular, to determine the connection of the material to guided discovery advice.

Other instructional design processes are available. The instructional strategy (used in the design of the domain material) suggests a way to support the processes of how concepts are acquired and how they should be taught, such as the material by Kemp (1985) which provides details on specific stages such as tools for evaluating learning gains (which may be used to supplement Merrill and Tennyson’s approach). Questions centre on how best to present a concept so that the learner can readily understand it and how to apply what is learnt for stimulus discrimination and generalisation, to be able to categorise between certain concepts.

To impose these concepts onto a hypertext structure, each concept can be represented as a hypertext node linked by superordinate, subordinate and co-ordinate concepts. A complete definition of the concept is needed; with a concept name, a list of critical attributes and its relation to other concepts. The hypertext nodes are used to organise a mental schema (a mental representation of a set of related categories). These slots contain information about the stimuli, which is used especially in learning and memory retention. Educational psychology research has suggested that schemata are structural entities comprising human memory and thought (Howard, 1987; Sprinthall and Sprinthall, 1990); and failure to comprehend may be due to selection of the wrong schema or a non-intended one. Designing material, which follows an instructional strategy for concept teaching, will make this process of understanding concepts easier.
Using conceptually designed material, supported by a guided discovery component, will focus the learner on the relevant concept and then support the understanding of the concept by illustrating characteristics of that node, with the addition of a concept map tool.

8.4.3 Designing Questions and Clues

The designing of questions and clues are important because they determine how the learner approaches the material. To determine how to design the learning episode to support guided discovery there are four principles:

1) The use of a detailed series of stimuli. These can be in the form of statements, during the setting of the scene, or as questions to elicit certain cognitive processes for discovery.
2) Each question should be designed to evoke a single, correct response.
3) The questions should be administered in a very specific sequence
4) These steps of smaller discoveries should accumulate until the learner discovers (or converges on) the target concept.

Therefore questions act as a stimulus for understanding the concepts contained in the material. They trigger the mediation phase of the S-D-M-R model (see chapter 4). During the mediation phase, it is suggested that the learner is engaged in a cognitive operation other than memory. In the guided discovery condition the learner will receive advice, in a question format, at several levels. As the learner works through the material, questions will appear regardless of the knowledge state of the learner (level 1 guided discovery). These are used to support general difficulties that the learner may experience with particular concepts. At the second and third levels of guidance the steps for discovery are increased to support the cognitive leap needed for progressing from the unknown to the known to formulate the correct cognitive schema. The questions highlight the attributes for understanding a particular concept, with the third level of guidance (level 3 guided discovery) commonly asking a question and providing the solution. The technique used for creating the questions is the conversion technique advocated by Mosston and Ashworth (1990).
The conversion technique involves the initial creation of a sequence of statements. These statements would resemble a lecture style format (referred to as style B, the Practice style, in the spectrum of teaching styles). These statements are then converted to questions whose answers are equivalent to the statement. The sequence of questions should then be tested on the target population to determine if each student is able to discover the target concept or understand the particular principle. This approach was used to design the sequencing of questions to guide the learner in the guided discovery condition. When questions were not used, statements outlining specific parts of the concept or principle were used instead. The use of questions, clues and attention-focusing statements were not used in the map condition or the unguided condition.

8.5 Other Issues in Guided Discovery System Design

8.5.1 Navigational Guidance

The design of a sequence of steps remains a particularly problematic part of the guided discovery style. Considerations should be: (a) the objective of the teaching episode, (b) setting the scene, (c) the size of the steps, and (d) the sequencing of the steps. It is suggested, however, that following the sequential steps for discovery provide only limited guidance.

Although learners may follow the steps and ‘discover’ the correct principle or concept, they need to find the correct starting point for entering the hyperdocuments and to carry out certain lessons in a specific order. Therefore system support is required at a navigational level. This is referred to as navigational guidance, and is used to support the discovery process at a ‘higher’ macro-level, and at the ‘lower’ micro-level. This is in addition to the guidance support within the actual steps (in the form of specific advice related to each specific discovery step). The aim is to provide limited system control of the navigational behaviour of the user based on a decreasing intervention strategy.
Navigational issues have been extensively discussed in chapter 5, in Research Issues for Hypertext, and is an integral part of the ‘lost in hyperspace’ problem. One of the major problems reported with the use of hypertext as an instructional form, is the orientation of the learner. Orientation describes the means by which users are able to identify their current position in the system, how they achieved that position and how to return to a previous position. Disorientation is a problem which is frequently observed in studies of hypertext users (Conklin, 1987) which will contribute to a detrimental outcome in learning. This is more prevalent among novice learners, where the ability to browse through many links will not guarantee learning (Mayes, Kibby and Anderson, 1990) and this problem is also identical to navigation in a WWW information space (Brusilovsky, Eklund and Schwarz, 1997). Specific to the topic of learning and navigation is the issue of curriculum sequencing.

Curriculum sequencing describes the order in which new knowledge units and skills are to be learned and the corresponding teaching operations used to present this. The use of examples and demonstrations, asking questions, online exercises and tests need to be presented to the learner in a specific order. In traditional CAI learning material the curriculum is predefined by the system developer, whereby an optimal path is provided for the predicted capabilities of the learner. In a hypertext environment the situation is totally different. Random ‘surfing’ through the hypertext space will result in either getting lost or a non-optimal path. WWW browsers do not give hints as to which pages are suitable to visit next, hence the requirement for some level of navigational guidance. Using the overlay model to collect a user profile, the guided discovery system provides general and specific navigation support.

General navigation involves a comparison of the navigational history of the student as the student selects links. If a conceptual node is seen as unsuitable for the learner at a particular stage in the learning, a message will be provided by the system. This can take several forms: (1) suggestion that a particular concept is not suitable to be learnt yet, (2) suggestion of an alternative area of the information space that has not been explored or missed out; and (3) advice about new links that have been switched on in the hypertext space that the learner is advised to explore. Randomly accessing information will not allow the learner to create a coherent cognitive mental model of
the domain. Providing an instructional module to structure the navigation can therefore support the discovery process.

Specific navigational support is also given within each lesson. If the learner selects a lesson and quits the lesson or selects part of a lesson without acquiring the necessary pre-requisite concepts, the system will intervene. The instructional advice is similar to those described for general navigational support, but there is the addition of advice to explain a specific principle which the learner may have a misconception about. Therefore support is given when following a particular sequence, and also at the cognitive level by assisting in the discovery process itself.

Advice is one of several ways that the system can carry out guidance. Another method is in the operation of the navigational buttons. Control via navigational buttons (Back, Forward and Contents Page) has been examined by Specht and Weber (1997). Their use of a NEXT button, in the ELM-ART Lisp system, was used to guide the learner to a page suggested by the system. This could allow the learner to request advice with the system checking for pages not yet visited or unfulfilled prerequisites. Using buttons to guide the user was also prevalent in the guided discovery condition of this project. For example, if the learner had selected a sequence to further explain a concept (level 2 guidance) the contents button would be switched off (with a message in the browser informing the user of this). The learner would have no option but to work through the whole of the sequence. This was because these smaller steps would lead the learner to understand the concept, through the reaching of conceptual sub-goals. Missing out any of these lower level discovery steps would create gaps in the steps, making their use ineffective.

Decreasing intervention was used as a principle for determining navigation and instructional support. System intervention, in terms of navigation and instructional advice, is decreased as the learner explores the domain and gains more knowledge and experience. Hence at the start of the exploratory process, the system continually monitors the learner's behaviour, matching it with an expert model of the same domain. Providing guidance at the navigational level and within each lesson. This will be reduced, whereby the system still continues to monitor but allows the learner to take more control in selecting which node to select next. Therefore the cognitive
scaffolding that is initially provided is gradually removed. Depending on the current knowledge state of the user (recorded as a student overlay model), the expert system component carries out a comparison between expert navigational patterns and those of the learner. Although not as complex as other types of expert system modules it was seen as sufficient for providing the adaptivity in feedback that the learner needed. Following sequential steps are themselves a form of guidance (because the learner goes through pre-specified discovery steps designed to encourage discovery), with the inclusion of control over the navigational process enforcing beneficial exploratory behaviour.

8.5.2 Interface Design Issues

There are certain design issues in this project specific to considerations of hypertext and the utilisation of an Internet browser to display the material. This section will begin with design issues of a hypertext interface and the implications that this interface design has for learning. The second part will examine issues for general interface design guidelines, the third area will examine specific issues related to web page design. The fourth area will examine the prototyping of the interface. The aim of this section is not to cover all aspects of interface research but to cite specific principles that have been used for supporting learning systems.

The user interface is seen as critical in determining the success of the learning process (Miller, 1988). It is suggested that the interface to an Intelligent Tutoring system is often the most neglected part of the design, in favour of investigation into the student model or the domain knowledge components. The problem in doing so is that if the student cannot operate the interface, then the remaining components are of no use for promoting learning (Baudendistel and Hua, 1987). As O'Malley (1990) argues, the interface should be transparent so that if the learner is using computers to learn about a task then this should not be made more difficult by having to struggle with using the system. If the learner has to concentrate on using the interface, then attention is drawn away from the domain being taught.

Therefore the requirement of the design is that it should be usable so that the interface 'disappears' for the user. Therefore a principle of design for educational
environments is that the interface should be responsive and consistent, based on the skills and expectations that the student already has; rather than acquisition of new skills (Baudendistel and Hua, 1987). A key part of this thesis is to minimise the amount of new skills to be learnt to operate the system, hence the selection of students already familiar with web browser technology. The interface was designed to utilise this familiarity using identical operational behaviour. Attention to the design of the actual format of the screen is important as it is generally slower to read from on-line documents than from paper.

The hypertext interface is defined by Dillon (1990) as a communication channel for the transference of material from the machine and the user. Operation of the interface can occur at the physical level and at the representational level. The physical level is concerned with navigation of hypertext using a keyboard, mouse and other traditional input devices. The representational level examines the construction of nodal metaphors and navigational functionality. Also issues of font size, colour and screen layout need to be examined in relation to specific hypertext issues such as buttons and link design.

Most interface design is in the form of lists of principles related to HCI. These can be on iconic design for domain representation, or for the construction of direct manipulation interfaces (Shneiderman, 1998). It is difficult to assess the effects that these interfaces have for learning, and the compromises that have been made in using such interface designs. For example, a requirement may be to display only a page of text, but how this affects the mental context of the material to the reader is not investigated (Nielsen, 1996). It is only now beginning to be investigated how to design hypertext web pages capable of supporting learning (Nielsen, 1996).

The principles for designing hypertext environments for learning remain sparse, and user interface design principles tend to be too general. In the systems in this project, the aim of user interface interaction is to achieve ease of use (such as reducing the amount of steps needed to carry out an operation) and also ease of learning (allowing the learner to focus on the domain material). Users still had to learn the hypertext structure and the use of navigational aids such as the navigational buttons and the links. But this functionality is explained both in the instructions beforehand and in a
A key user interface principle is to present the material in a consistent manner. Advice was given to highlight any changes, such as additional links being added to the contents page. Brusilovsky, Specht and Weber (1995) argue that too many large changes in the interface can upset the learning process. Therefore any adaptation at the interface level should be stepwise and only when there are reasonably sized portions of new material, such as a new chapter. Another principle is to minimise the cognitive processing needed to operate the system. Therefore there is no keyboard input and only mouse selections (this would encourage students to participate in the experiment who feel less comfortable using a keyboard to negotiate the web pages). Along with this are specific issues related to using WWW technologies that also had to be incorporated into the design of the interface.

Using the WWW to present the hypertext information creates several implications when designing the user interface. Nielsen (1996) has outlined the ten most common mistakes in web page design, five of which are considered in the design of this system. These are outlined below:

- **Using Frames** - dividing a page into frames can be confusing for users since frames break the fundamental user model of the web page. In terms of learning: the learner may not know which frame to concentrate on, may not notice changes in the information contained in a particular frame, or the function of that frame. Therefore the number of frames used was deliberately kept down to four. An explanation is given of the purpose of each frame with instructions and demonstrations to reinforce this. A flashing header was added to the advice window. Colour is seen as a way of drawing the user's attention to an important piece of data or to an important position in the display (Sutherland, 1996). During the pilot phase it was identified that some subjects found it less easy to spot when the advice had changed or if the advice window was filled. Colour was also used to focus attention on particular parts of the concept map.

- **Long Scrolling Pages** Only 10% of users scroll beyond the information that is
visible on the screen when a page comes up (Nielsen, 1996). But if the pages are subdivided into smaller ‘chunks’ this may cause difficulties in terms of learning. Long, scrolling pages allow a reader to advance in the text with less loss of mental context than if they were following a link. Retrieving a page may create a delay which could detrimentally affect learning (chapter 6 discusses the effect of network latency on learning). The size of web pages was dictated by this issue of scrolling and also by the design of the concept (usually one concept per page).

- Lack of navigation - Users may experience difficulty finding information, hence support should be given in the form of a strong sense of structure and place. The provision of a concept map and guided advice, both in terms of learning the material and navigational behaviour, further support this process in the guided discovery condition.

- Non-standard Link colours - Nielsen suggests that links to pages that have not been seen by the user are blue; links to previously seen pages are purple or red. This colour scheme for hypertext links should be retained and kept consistent, since the ability to understand which links have been followed is one of the few navigational aids that is standard in most web browsers. The link colours in the hyperdocuments have been modified so that they remain blue. It could be criticised that learners may not know which pages they have visited. Hence additional navigational support, such as messaging and feedback based on user tracking, minimises this possibility.

- Overly long download times - traditional human factors guidelines indicate ten seconds as the maximum response time before users lose interest. On the web, users have been able to increase this limit to fifteen seconds for a few pages (the effects of this for learning are discussed in chapter 6). Placing the material on a campus server, with access from a local client will minimise the download time. As has the design of Java applets (the code embedded in the web page) for tracking, being kept deliberately small.

To support navigation further, messages were displayed in the browser itself
informing the user what would happen if they were to select a particular link (e.g. "this link will take you to a sub-section of the material"). This was used to help learners quickly understand the function of the hypertext links, to reduce the time needed to understand how to operate the system. This resembles the "balloon help" which are used to show information about the function of certain buttons when the user places the mouse over it. This was found to be beneficial for those who had less experience of using the browser (Brusilovsky, Specht and Weber, 1995) and resembled the occasional hints given by the system, which helped users memorise functions in the system much quicker (Franzke, 1995).

For more information on designing web pages for the Internet, the Sun Guide to Web Style (1996) provides a discussion of factors such as intended audience, graphics and link design. When designing a hypertext environment for the WWW there are therefore additional web-specific factors that need to be taken into account, as well as hypertext and learning factors in the design of the interface to the learning environment. Therefore time was spent on the prototyping stage to continually test the interface on users to ensure that it was designed so that the learner spent more time learning about the domain rather than about the user interface.

Prototyping is the testing of a part-functional or fully functional version of the system. Guidelines from Hackos and Redish (1998) and Wilson and Rosenberg (1988) were used to determine how to carry out testing of the user interface. Some of the benefits of prototyping are the testing of system-specific questions; which were not answerable from the general guidelines which have been discussed so far in this section. Some of the questions asked were: (1) did the interface match the user's mental model, (2) did it match the user's way of working (3) did it cover the tasks that the user was expected to do with the system, (4) did it provide messages where and when the user needed them, and (5) whether there was consistency in the look and feel across screens. Feedback from user testing increases the probability that the system will perform as expected. Therefore several different interface designs were tested on colleagues and in the pilot study phase.

Providing several prototypes allowed the users to participate early in the interface design phase as well as help in the debugging process. For example in the size of
frames, concept maps need to be displayed alongside adaptive advice, domain material and a Java navigation bar. Determining the compromise in screen estate was partly influenced by subjects commenting that they may not pay attention to particular windows just because of the size, and not because of the perceived usefulness of the functionality in that window. Interface design in the guided discovery system used in this project is influenced by issues specific to hypertext, the WWW and the goal of designing a system for learning. Guidelines for WWW learning systems remain general, hence the need to carry out prototyping in the design phase to determine any problems in the design of a learning-specific interface, using Internet browser functionality.

8.5.3 Designing Online testing

Online testing was incorporated into the lessons on Electronic Logic, consisting of multiple choice questions. The learner would work through a set of questions, selecting from a range of possible answers. The reply was analysed and a score given for the complete test for that particular lesson. As well as the score, the model answers were also displayed, with advice concerning where the learner may have gone wrong, identifying the concepts and explaining them in an attempt to correct the misunderstanding. If there were any mistakes, the learner would be informed of new areas of the hypertext space that had been opened to overcome these misconceptions (these are the second and third levels of guidance for aiding understanding of the material – section 8.4). A discussion will centre on the other types of testing that could have been chosen, and will end with a specific outline of the testing used in this system.

The need for some form of facility for assessing learning on the WWW is part of a plethora of issues that educators face when setting up a virtual university (Whittington and Sclater, 1998). Measures and assessments of achievement and outcomes are an integral part of the teaching and learning process. The enhanced interactive capabilities of the WWW provides the means for assessment of student learning. Rather than a reliance on conventional essay and examination submission, other evaluation measures can be used such as portfolios, summary statistics of learners'
paths through instructional materials, diagnosis, and reflection and self-assessment (McLellan, 1993).

Pang and Edmonds (1997) consider the possibilities in Java to take free-form answers, graphical drawings and scratchpad input. DeJong (1992), in a hypertext learning environment for language learning, used an empty scratchpad on the screen so that learners could make notes and test hypotheses; and this too could be examined. There still remains a lack of research into forms of testing able to use the capabilities of the web (Debreceny, Ellis and Chua, 1995). Research into general assessment for distance learning using the Internet has already been discussed in chapter 6 and a more specific examination of testing for hypertext systems will follow.

Many forms of assessment were considered (see chapter 6, Issues in WWW and Distance Learning). Such as Computerised Adaptive Assessment (CAT), whereby the diagnostic evaluation tests could dynamically adjust to the examinee's knowledge. Diverse question sequences would be given according to the responses given by the student as the material is learnt (Welch and Frick, 1993). Adaptive tests generally employ a set of questions ranked in order of difficulty, and answers obtained at any given level dictate whether the ensuing questions will be chosen from a higher or lower rank. Trentin (1997) discusses future research of adaptive testing in an adaptive hypertext learning environment with a system named HyperDelfi. But the benefits of CAT requires further research to determine whether the effort is worth the gain in terms of the resources needed to develop such a system although it remains a possibility for future consideration.

Multiple-choice testing, previously used in hypertext research, is also applicable in the design of WWW documents and learning materials. It was used in this system because it provided a measurable degree of progress which was analysable by the system and was particularly suited to the domain of electronic logic; that of non-ambiguous, non-contentious concepts and principles.

Fixed-item testing was used in the form of a fixed sequence of questions administered to all the subjects regardless of the experimental condition. This was used to fulfil two aims: (1) as a form of self-assessment for learners to gauge how well they had
done; and (2) as a source of information for creating the student model to provide feedback and advice (De Bra and Calvi, 1998).

In terms of self-assessment, it was theorised that providing online testing, with immediate feedback would motivate the learner by providing a form of educational goal (that of achieving correct answers), and would help focus the discovery process. Because the subjects were given immediate feedback, they could decide whether to rectify any misconceptions or proceed with the next lesson. In the guided discovery condition the subjects would receive additional advice concerning their mistake and be led through a discovery process structured to help overcome these misconceptions, or tangential steps (Mosston and Ashworth, 1990). In the other conditions there was no such guided system support.

The answers and the test score would be used to structure the exam feedback and subsequent guided advice, with an identification of the possible concept that the learner answered incorrectly. The assumption was that if they were taken through the material again, the addition of guided advice would create a different approach to understanding the material. Therefore online testing is linked to the adaptive guidance aspect of the guided discovery system used in this project.

8.5.4 Selection of Software and Hardware for System Development

This section discusses the selection of the software and hardware used to construct and implement the system used in this experiment. In terms of the functionality required for providing guidance there would be the requirement of a 'soft' ITS component. Guided discovery is based on the premise that the learner would have control over the exploratory process, with the tutoring component providing differing levels of advice according to navigational behaviour and results from online testing. Because the environment was more open-ended, in terms of the user's ability to control the learning process, there was no requirement for the system to analyse every action of the learner but to take snapshots instead. Therefore the requirement was for an inferencing mechanism; but without the complexity or computational power of a full-blown ITS.
This approach is similar to the minimalist ITS approach, whereby the system is built by simplifying parts of an ITS but still striving to maintain as much pedagogic intelligence as possible (Gutwin et al., 1993; Brusilovsky et al., 1994). The inferencing mechanism should be able to analyse student behaviour, compare it to the overlay (expert) model that the system has, and reach instructional decisions according to the state of the learner’s knowledge. It is not the aim of this project to develop new ITS components but to use parts of these approaches for new applications on the Internet. To provide individualised instruction and guidance, there has to be storage of each user’s records of navigation and progress. The inability of the WWW to identify or track the user will make individualisation of system guidance very difficult (Ibrahim and Franklin, 1995). Web links are basically just calls to the server from a remote client. To transcend this statelessness of internet protocol there has to be the development of a system of user tracking that allows the selection of hypertext links to be differentiated and allocated to that particular user. This is the use of Java to build applets that can identify each learner. Related to this network issue is the requirement for a system to be accessible via the WWW browser.

8.5.4.1 Using Java in a Network Environment

Java has gained particular popularity since it was formally announced in May, 1995 as the programming language for the Internet (December, 1995), with the rapid growth of support for Java and the expansion of newsgroups and online magazines to cater for developers needs.

Java is cross-platform with development kits and Java-literate browsers provided for most popular operating systems such as Apple Macintosh, Windows and UNIX. The latest versions of the most widely used browsers, such as Netscape’s Navigator and SpyGlass’s next generation Mosaic, incorporate viewer capabilities which can run Java applets (programs written in the Java language) and provide facilities for writing Java Script (a high level version of Java) (Symantec Corporation, 1996).

A Java application is a standalone application which can run independently of the browser whereas Java applets run within the browser. Initially the user will select a hyperlink on the web page. The browser will load the corresponding web page and if
it contains a Java applet this will automatically be loaded with the web page onto the client. The Java applet will run as long as the web page remains on the browser. When the user exits the web page, 'garbage collection' will usually take place whereby the applet will be removed from the client and the systems' resources are restored to its previous level. This appears seamless to the user as the only act the user has to do to load the Java application or applet is to click on a link. It is this ease of use which adds to Java's potential for changing the way web pages operate, and the ability to create tools for learning online.

Online magazines show that a large number of web users are interested in designing or at least being familiar with Java technology. JavaWorld (IDG Communications, 1996), a more general online Java magazine, has only been in production since March 1996, but already regularly features in the top five sites with net users visiting every week and a readership of 25,000 users registered world-wide. More specialised technical journals, corporate training courses teaching Java, and the implementation of Java and WWW protocols into company Intranets (Hewson, 1996) suggest that Java will continue to be an important programming language for Internet development.

Therefore Java as an environment for developing applications is well supported and its popularity is continually increasing. The key to its appeal is that learners with a fairly modern computer and the latest Java-literate browser can access the application. The Netscape web browser offers Java-capability and remains the most popular browser with an estimated installed base of 38 million users by 1996 (Netscape Communication Corp., 1996). This suggests that Java will impact on the lives of most future Internet users.

8.5.4.5 Utilising Internet Functionality

WWW accessibility was an essential part of the software requirement. Browser accessibility has played a key part in the explanation of the exponential growth in the popularity of the WWW. In terms of distance learning, users could have a plethora of different Internet browsers, different levels of computing power and various levels of computing experience. Hence for this course to be accessible for those with a
network connection and an Internet browser, the guided discovery environment had to have no installation of any specialist software or the opening of new windows or helper applications on the client side. Installation complexity had to be kept to a minimum. The system used hypertext mark-up language to create web pages. Keeping the functioning and operation of the guidance learning environment within the Internet browser would offer other advantages; allowing the functionality to be integrated into future systems which could offer other capabilities to support the learning process, such as remote video connection for international collaborative teaching (Koch, 1995).

Sophisticated uses of the WWW (in providing educational programs able to be executed remotely for example) and utilising the features of this environment (hypertext and remote access), remain almost non-existent at this present time. Traditional CAI systems provide some principles for the design of WWW-based educational systems but the actual programming languages for supporting these principles remain lacking. Some conventional hypertext systems provide programming languages able to extend the functionality of hypertext systems, such as Guide’s LOGiiX (OWL, 1990) or KnowledgePro (Knowledge Garden, 1991) which are able to combine the functionality of hypertext with multimedia, expert systems and procedural programming. Therefore these can attain a certain degree of ‘intelligence’ but lack the functionality for use over the Internet required for this experiment, such as user tracking and sophisticated web user interface control. These have been continually improved to provide greater web functionality but are not yet at a stage where they can provide an integrated tool for building this specific type of learning environment.

Other systems such as Authorware have begun to explore the use of the web, with the application of Shockwave, to ‘shock’ Authorware material in order to display it on the web. But the web is still seen as a display tool similar to a television, rather than an interactive, user-responsive instructional environment. Lotus Notes have also begun to explore the specific education requirements of the web, which are very different to the normal use of Notes in a business situation. This is to enhance Notes into more than a messaging tool, to develop greater levels of interactivity. However this does not involve user tracking, or adaptive instruction of the material.
Adaptive hypertext is a possible way forward to create tools for building adaptive educational systems (Eklund and Brusilovsky, 1998). The literature on the evaluation of adaptive link annotation in educational hypermedia is limited and sometimes characterised by anecdotal evidence from sources of less formal experimental designs. There is clearly a need for continued studies in this area as adaptive educational systems on the WWW remains an under-investigated but promising area.

Rather than radically modifying current authoring packages into displaying material on the WWW, with complex programming compromises and add-ons, it was suggested that a system should be built from scratch using the Java programming language (Gosling and McGilton, 1995). The advantages of using Java for educational environments were discussed in this chapter and by Pang and Edmonds (1997).

In terms of education benefits, Java applets were built with separate identification of the learner encoded into the applets; feeding into the implicit student overlay model in the form of continually updated files stored on the server. A client-server system was constructed to control the serving of the web material and collection of user-tracking data.

Hardware, like the software, should be fairly standard, with no assumption that the user has particular specialised computing equipment. Hence the requirement is for a typical system set-up without the need for additional input or output devices beyond the ones used for conventional ‘surfing’ of web pages. Because of the multi-platform feature of Java it remains less relevant whether the user is learning from a distance using a PC, Macintosh, Sun Microsystem or Silicon Graphics Workstation. As long as the prerequisite up-to-date browser is installed, the system will be able to function through the browser. Most learners will use a PC running on Windows, but the system operates on Macintosh or Sun workstation. This ease of use will allow the learner to overcome hurdles concerning technical worries, as learners not comfortable with the system may experience technostress (Shneiderman, 1987; Hedberg and McNamara, 1989). Switching on a familiar computer, facing the same browser, using
the same operations as conventional web-surfing will reduce the cognitive load on the learner.

Current programming languages for the creation of educational hypertext environments lack the ability to use the WWW in an interactive manner, or allow tracking and immediate responses to user activity. Others are overly complex and require detailed user modelling, which is less of a requirement for this educational system that relies on a learner-led, exploratory approach to learning. Any educational hypertext environments based on the WWW that are able to track the user, provide individualised instruction and guidance remains at best at an experimental stage. Hence the requirement to build a hypertext educational system for the WWW, composed of Java applets passing data to a Java application.

8.6 Modelling the Learner in a WWW Guided Discovery Hypertext Learning Environment

It remains difficult in hypertext to know exactly what the user is doing all the time, therefore it is hard to evaluate the user’s cognitive status. Questions can centre on: (1) whether the learner understands the text that they have read, (2) if the visited nodes have been selected for sensible reasons, and (3) if the navigational behaviour is haphazard and inefficient.

Quantitative analysis of user log files of a hyperdocument, carried out by Taylor and Self (1990), revealed a lack of rationality in the users’ actions, making it very difficult to predict their behaviour or the reasons for this. Typically there are episodes of unanalysable activity, separated by long gaps, with no user actions. It was difficult to ascertain what had been learnt or the reasons for particular learner actions. Thus the:

“automatic monitoring of individual actions seems a dubious proposition” (Taylor and Self, 1990).

They did not adopt a particular strategy, following particular goals that they had
determined as important at particular moments in the exploration. Hence adapting instruction to an individual's preferred learning strategy is highly problematic.

The lack of established research on student modelling in an educational hypertext environment only compounds the problem when applying this to the WWW. WWW users are learning by reading as opposed to learning by doing, where it is possible to monitor the learners' problem-solving activities. Users will most likely adopt opportunistic planning styles with no planning beforehand. Instead they tailor actions using a step-by-step approach to the situation. This is because by definition, it is relatively easy to explore and recover, in a hypertext environment.

Overlay models (previously referred to in section 2.4.2) have been criticised for encouraging the view that the student is a 'subset' of the expert. This criticism is not so clear-cut. The subset view originates from confusion in the characteristics of the overlay model. With reference to the section on intelligent tutoring systems (chapter 2), the generative ability dimension is often confused with the cognitive scope dimension (i.e. the presupposition is that a higher generative ability user model leads to increased cognitive engagement, an overlay model is not generative hence less cognitive engagement). The suggestion in this system is that a system that uses an overlay model can still incorporate information about the cognitive growth of the student, and it can still have deep conceptual scope. When it becomes apparent that there are two dimensions that are different, then it becomes possible to have overlay models that incorporate overlay bugs (mistakes which the user makes), strategies and other types of user behaviour. Therefore overlay models can possess a detailed understanding of the student, hence its use in the systems in this project. A comprehensive overview of user modelling is given by Clancy (1986), VanLehn (1988) and McCalla (1992).

In terms of student modelling in WWW-based tutoring systems the difficulties of user modelling are exacerbated. The learning system has to play the role of the teacher to a large degree. In a distance learning situation no teacher is directly available during learning who can carry out the task of adapting the number and nature of new concepts presented to the learner's current state of knowledge (Weber and Specht, 1997). WWW browsers only annotate visited links but are not able to provide any
guidance as to which pages are the most useful to be selected next. In this situation an individual learner model can provide the information that can be used by the learning system to adapt the presentation of the pages to the particular user.

A simple type of user model similar to the overlay model may be sufficient to represent all the necessary knowledge for individualized sequencing and adaptive guidance in the hypertext (an explanation of adaptive sequencing and guidance is given in chapter 7 on Adaptive Hypertext and WWW). The simplest form that this takes is as an information base containing information about whether an item has been learnt. Examples of such systems are ITEM-IP and HyperTutor (Brusilovsky, 1995). In WWW-based learning systems, attempting to maintain an individual user model and also observing and diagnosing the learner's knowledge state is extremely complex (Weber and Specht, 1997). Only a few systems have been built that provide simplistic forms of individualised sequencing and adaptive hypertext guidance. It is suggested in this thesis that providing support based on decreasing intervention, different levels of guidance and predominately learner-controlled navigational selections, using an overlay-type model, will result in measurable gains in learning and satisfaction.

In terms of obtaining evidence from the web pages with which to generate the student model, this is partly done implicitly by monitoring the student's problem solving behaviour. Hence making the learner active in the discovery process by taking online testing, and also through the selection of links embedded in the web pages. These will provide detailed records of the learner's level of domain understanding and navigational behaviour.

In this project, the guided discovery learning environment on the WWW is designed to monitor the user's interaction and use them as a measure of what the student is believed to have learnt. The student or learner model consists only of the nodes that the user has visited. The user's interactions are compared to an expert model of the domain. The system adapts the guidance accordingly, by making specific links available, providing instructional cues at key points in the interaction to direct the student to nodes that have been overlooked or have been accessed in an incorrect sequence, and different types of advice according to different levels of guidance. This
is primarily a qualitative approach to modelling the learner to provide individualised instruction and support. The user model is very much along the lines of an overlay model, but it is powerful enough in terms of providing a level of detail that can provide adaptivity. From the literature, there is the tacit assumption that tutoring based on fine-grained student models will be more effective than tutoring based on course-grained models. Fine-grained student models describe cognitive processes at a higher level of detail, course-grained do not do this. But this assumption needs further investigation to determine whether it is worth the effort. The suggestion in this project is that there may be less of a requirement for sophisticated user modelling approaches for this experimental system for exploring guided discovery principles. The compromises made when using an overlay model has been outlined in this section, and this approach to user modelling is sufficient for providing limited adaptivity.
8.7 The Synergy between Navigational Guidance, Sequential Guidance and Discovery Steps for an Integrated WWW Hypertext System

The discussion in this chapter has focused on the components that provide guidance in a WWW hypertext environment. It has been identified that there is a requirement for individualised support for the learner both at the navigational level and the micro-level (the specific steps which are used to lead to the discovery of a particular concept or principle). The structure of the system is depicted as figure 15.

Using the S-D-M-R process (discussed in chapter 4), the stimulus (S) is determined beforehand and embedded as a Domain model and in the Instructional model. The discovery (D) and mediation (M) process (where there is a search for a solution) is controlled by system guidance to bridge conceptual gaps in knowledge. The inclusion of a concept map will aid this. The response (R) is displayed in the interface in the interaction with the learner. This is in the form of specific advice related to a concept, control of navigational buttons, and confirmation of the correct solution.

The guidance component operates at the navigational level to maintain educationally effective navigational behaviour and also at the discovery step level, to lead the learner through a sequence of steps to bridge the cognitive gap for understanding a particular concept. The instructional module matches the expert records with those of the learner (recorded as an overlay student model). The expert system module determines the web page to be selected (this maybe accompanied by advice rather than just the retrieval of the node chosen by the learner). System feedback is displayed in the interface, both with messaging within the browser and also with overt messaging in the form of advice. This is further controlled by modifying the function of the navigational buttons. Online testing and analysis of the links selected provide information used to determine the current knowledge level of the learner.
Figure 15: The Tiered Structured of a Guided Discovery WWW Hypertext Environment
Although the components resemble an Intelligent Tutoring System (see chapter 2) there are many differences. There is less of a reliance on a user model driven approach, with the learner being allowed to explore parts of the hypertext space before system intervention. The learner is given control with the option of ignoring system advice; and the inclusion of online testing with immediate scoring allows the learner to carry out self-assessment concerning knowledge progression. This tiered structure allows the system designer to examine each part of a possible learning environment, which is adaptive to the learner and usable for the WWW. These characteristics are reflective of the interpretation of a guided discovery pedagogical approach proposed in this thesis, for learning using a WWW hypertext environment.

8.8 Guidelines for the Design of Instructional Hypertext

The development of educational hypertext for instruction should be based on several considerations. To determine whether an application is suitable for hypertext, Shneiderman (1998) proposes three rules: (1) that a large body of information is organised into numerous fragments, (2) the fragments relate to each other and (3) the user only needs a small fraction at any one time (Loon and Chung, 1991). This is a very basic description but provides a starting point for converting learning material into hypertext.

Romiszowski (1992) provides a more detailed approach, examining the particular design of many types of media used for educational purposes such as simulations, interactive video systems and interactive computer-based learning. Aspects of these designs can be applied to a hypertext environment for guided discovery. Some of these aspects will be discussed to highlight decisions that have been made when designing the system used for this experiment, and are useful for the design of educational environments generally. When examining the specification for designing an educational hypertext system, there needs to be consideration of several factors: the purpose of the system, the task and content of the system, user characteristics, type of media, node types, link types, network representation, navigational freedom,
Navigational aids, authoring needs and evaluation approach. There are other considerations, but these form the basic decisions that need to be made for design.

The purpose of the guided discovery and conventional hypertext documents was for students to learn about electronic logic by browsing the information space. The mode of use in the hyperdocuments was to be read only. No authoring permission was given to either annotate or add further hypertext links to the material. This was because the aim of the experiment was to determine if the guided discovery component of the material would be sufficient to promote learning using the same material as the conventional, unguided hypertext condition. Introducing authoring capability would change the nature of the learning and may also add to cognitive overload.

The type of media available was restricted to text and images only. The images were diagrams of electronic logic gates and circuits. This form of material was seen as sufficient in providing an understanding of the principles and concepts without the need to use sound or simulations. The type of node was a link to a whole page of material rather than to areas on the same page as the originating link. Learners could select a hypertext link, which was the concept label, to reach another node containing details of the associated concept.

Other types of links were also created for navigational purposes. These were a forward button, back button and a button to link to the contents page which would move the learner to the next node, back to the originating node or to the contents page respectively. The actions of these buttons in the navigational panel would remain the same, except for the guided discovery condition whereby they would change according to the state of the learner. For example if the learner failed the current online test, in the guided discovery condition the learner would be taken to a different contents page with specific advice about the failed questions. Otherwise, if successful, it would bring the learner to the conventional contents page. This was part of the approach that the system would use to guide the learner. The subjects were advised to take the online testing so that their exploratory behaviour would be more purposeful; rather than randomly browsing with no educational goal and hence losing motivation.
The Internet browser buttons were not switched off, although other studies that have used the WWW browser had done so (Whittington and Sclater, 1998). This was because the system should replicate a real non-experimental learning situation at a distance, whereby the system should not control the functionality of the browser but instead allow the user to retain control. The subjects were told not to use the browser buttons in the system instructions and the pilot study showed that they were satisfied in using the navigation buttons provided by the system.

The representation of the hypertext network was constructed in terms of a conceptual model of the domain. This is discussed in terms of a node level and a global level. At the node level, concept maps would represent the position of the concepts associated with a particular node displayed on the web page. There are no clickable areas on the concept map, and scrollbars would allow the user to view larger maps. The benefits of concept maps have been discussed in chapter 5.9, and even non-interactive concept maps can provide support in understanding concepts as well as navigation. At the global level, there is a semi-dynamic organisation of links. As the learner navigates the conceptual space, the system will intervene by providing links to different sections of the material which the user may have missed out, or the guidance component will open links, accompanied by relevant explanations for selecting that link. As the learner progresses through the material, new links are opened in the contents page so that these can be explored, without providing too many navigational choices at the beginning of the exploratory phase.

The amount of learner freedom to explore the domain is dependent on the experimental condition. Users of the map condition and the unguided condition are able to select any links in any sequence, hence learner freedom is at a maximum, resembling general types of tutorial web sites currently available (chapter 6 and chapter 7 discusses these drawbacks). Those in the guided discovery condition have the exploratory process constrained. This constraint is reinforced by adaptive system support in the form of reduced links, guidance in the form of advice and overt system intervention when selecting non-optimal links. The navigational aids in all three conditions are a navigational panel (with buttons) and hypertext links. Those in the guided discovery condition and map condition also received concept maps reflective
of the local conceptual space. The guided advice could also be viewed as a type of navigational aid, but has been specifically made to enhance understanding of the concepts.

In terms of the development environment, the hypertext authoring shells were seen as less suitable for WWW-based tutoring environments as they remain at a developmental stage. The functionality required by this project, for WWW user interactivity and tracking, deemed it necessary to build the components of the guided discovery system. Other systems from adaptive hypertext are predominately experimental.

To evaluate the success of the guided discovery approach, evaluation was in the form of measurements in learning outcome and user satisfaction. Comparisons were drawn between the subjects in the guided, map and unguided conditions (Control group). These were also supported by analysis of the history files and interview responses; to gather information about navigational behaviour, cognitive development in terms of learning attained by each lesson, and interviews to allow open-ended comments about particular aspects of system use.

8.9 Designing the Instructional Strategy for promoting Guided Discovery.

The earlier sections of this chapter examined the construction of the material using the conceptual approach devised by Merrill and Tennyson (1977), the design of concept maps to reflect the structure of linking concepts, and the selection of software and hardware. There has also been an examination of issues specific to designing educational hypertext systems. This section will discuss the stages in the process of developing the hypertext documents. The stages are explained in terms of five stages:
Stage 1

The initial stage was the creation and collation of material to be used in the experiment. Lecture notes on this topic, web-based material and other types of instructional textbooks were studied to investigate the presentation and explanation of this subject domain. This included identifying key concepts in the material, dividing the concepts into lessons and providing an idealised, sequence of learning (see section 8.4.2 for a description of how the material was divided into concepts). The material was examined for depth and quantity of lessons to be covered, to determine if it was sufficient as an introductory course in this topic. Two lecturers carried out an assessment of the paper-based version of the material. An analysis of the subject population was carried out to determine which were able to be included in the experiment. This included an initial exam to gauge past knowledge of electronic logic.

Stage 2

In the second stage, an examination of how to apply guided discovery learning principles to the material was undertaken. As this was carried out, it was used to structure the material into a hypertext network. The content of each node was planned, with links being defined between related nodes. An analysis was carried out to establish how difficult it may be for the learner to gain a conceptual grasp of each concept (node). If it was considered that the concept was particularly difficult to grasp, several smaller steps were included to act as a 'cognitive bridge' to help the learner make the conceptual leap in understanding the particular concept. Along with this was the development of advice to allow the learner to approach the same concept, from a different viewpoint. What was essential to understand was that the domain material in all three conditions were identical. The difference was the breakdown of the understanding into further smaller steps, with the guided advice being the factor in supporting the learning, coupled with system support over the navigational process.
Stage 3

The third stage determined the form and operation of the navigational aids. These navigational aids were tested, with the concept maps being developed alongside the formation of a network of hypertext nodes. The context in which the information was to be displayed was determined, along with how to access nodes, navigating backward and forward through the material and when online testing would take place. The material was left with a high degree of exploration, so that the learner could follow a non-linear path through the material if desired. This may encourage the learner to explore the domain space, making them active in the discovery learning process.

Stage 4

The fourth stage consisted of the development of the hyperdocuments from the initial paper-based versions. One of the lecturers from stage one assessed the accuracy of the translation of the material into hypertext format. Checks were made concerning language consistency and clarity. Diagrams were included which would aid understanding of the concepts, along with additional examples of the concepts. The inclusion of guided advice was linked to secondary levels of guided discovery. Therefore if the first level of guided discovery steps was not enough to support conceptual understanding, the user could select a secondary level which would reduce the steps needed conceptually to understand a particular concept. The online testing was also implemented into the system and tested to ensure that learners knew how to answer the questions and that the questions tested specific parts of the knowledge to update the user model. The user model was used to analyse navigational behaviour with the construction of advice to remedy non-optimal navigational behaviour. The learner could ignore the advice as well as the lower levels of guided discovery support, therefore maintaining user freedom with minimal system intervention.

Stage 5

The final stage examined the screen design and also investigated methods for focusing the learner's attention. Due to increased browser functionality, the screen could be divided into a multitude of smaller 'frames', each displaying a separate web page.
Decisions were made concerning the size of the advice window, the concept map window and the materials window. A compromise was made in the size of the frame in which to display the maps. If it was displayed too large the learner could not obtain a clear view of the organisation of the concepts and how they were linked. Too small and the text became illegible. The aim was to reduce the amount of scrolling the user had to carry out to read the material, advice or the concept map as this would detract from the learning with excessive scrolling causing frustration. It was found that it was generally more difficult to read from the screen than from a paper-based, linear version (O'Hara and Sellen, 1997) therefore caution was taken not to clutter the screen. The consistency between nodes was also considered to be important, with links acting in a consistent, predictable manner. The concept maps and advice were examined to ensure that they focused attention on the critical information that needed to be understood.

In terms of appearance the differing links, headings and text were given different font and colour attributes. The use of different colours and font sizes was kept to a minimum to reduce the amount of information the user had to learn to operate the system; but these visual aids would impose structure on the material. The pilot study reported that red font helped to focus attention on specific parts of the material essential for understanding. The nodes were evaluated to ensure that the information they contained was correct and that the advice given was brief but understandable.

8.10 Summary and Conclusion

This chapter has discussed the construction of the components used to create a learning environment able to provide varying levels of guidance during the discovery process. This incorporates not only hypertext issues, but also WWW specific issues concerning interface design. A method has also been given for the construction of the learning material, using conceptually effective instructional strategies, and the addition of a concept map tool to reinforce understanding of the concepts. The design of the hypertext structure, using this approach, would aid in conceptual learning.
Advice was also linked to an assessment of how difficult it was to learn particular concepts.

There has been a discussion of the stages that have led to the creation of the guided discovery system. The testing and prototyping that was carried out to assess usability both of the interface and the other experimental conditions was also discussed. Finally there has been a convergence of navigational methods, discovery steps and system components to create adaptive support for the individual learner. It is suggested that this system, based on guided discovery, with the degree of support that it provides for the exploratory process will lead to greater gains in learning and in user satisfaction than a conventional hypertext system can, with or without a concept map. The architecture for the guided discovery hypertext learning environment is applicable to other domains rather than just electronic logic. Using the framework of teaching styles provides a design template of the learning sequences. Dividing the design process into clear stages such as the preimpact, impact and postimpact phases. Issues such as navigational guidance, interface design and online testing all illustrate the complexity of building such a system.
Chapter Nine

Research Evaluation Strategy

9.1 Introduction
An evaluation methodology is needed for the design of the experiments and the subsequent collection of data on learning outcome and user satisfaction, to determine how to research and collect this data in a valid and reliable manner.

Past research into CAI (Entwistle, 1990) suggests that educational research of innovative teaching is often carried out in a less structured experimental manner, using a classroom setting. Because the context is educational there is a need to examine the domain material, the teacher/learner relationship and the setting in which the learning takes place. A description will be given of the experimental conditions, followed by an examination of evaluation requirements followed by how these will be fulfilled.

9.2 An Overview of the Research Procedure

Three web-based learning environments were developed, each containing the same subject material but differentiating in the functionality and support that they would provide to the learner during the learning process. The experimental conditions were a guided discovery condition, a map only condition and an unguided condition.

The guided discovery condition is composed of three levels of advice. The first level of advice is primarily static and linked to the currently viewed material. The second type is administered after the online test session where the user receives feedback on
the incorrect answer followed by an explanation of the principle tested, including recommendations about where to proceed next. The third level of guidance advice is in the Further explanation stages (revealed by the system and related to failed parts of the online test). Each level of guidance acts as a stimulus to evoke the learner to question the material and to employ different approaches in viewing the principles contained in them, creating a level of dissonance and a subsequent search for an answer. This is supplemented by a cognitive tool: the concept map. It is the merging of all these functions to form a guided discovery approach which forms the main basis of this research project. The first system (guided discovery condition) would adapt the advice and hypertext links when gaps were detected in the learner's knowledge. The material was designed using a structured instructional approach, with the advice designed in the form of questions and the sequencing of material into discovery steps. This was coupled with the switching on and off of hypertext links during different phases of learning.

The second system (map only condition) contains the same domain material as the guided discovery system but without the advice component, hence no overt or covert guidance. The learner was free to explore all the lessons at any time in the learning process. The links remained visible throughout the learning session. The advice window was left primarily empty; apart from displaying the name of the last lesson completed, and the results of the on-line testing. The concept map remained the same as in the guided discovery condition.

The third system was the exploratory condition. The map and the advice from the guided discovery condition were not available. Minimal advice, concerning results from the online test, was identical to the map only condition. All the hypertext links were switched on, as in the map only condition, and the learner was free to explore any lesson in any order.
9.3 Preliminary Results

The majority of users answered that the amount of material available to explore was too much, not in terms of the hyperspace to explore but the sheer number of lessons. It was not expected that learners would complete all the lessons. After consultation with a Computer Science Lecturer, it was ascertained that the material would be covered over 3 lectures, with each lecture session spanning over 2 hours. Hence it could be argued that the learner was attempting to compress 6 hours of lecture material to be learnt and understood into a one-hour session on the Internet, an unrealistic goal.

Although it was stated at the beginning that the learner did not have to complete all the material some did manage to do so, illustrating the differences in speed and pace of individual learning. The initial premise was that they were unfamiliar with the system, especially in the case of the Guided Discovery and Concept Map conditions; and also had minimal knowledge of the subject area. Responses from the interviews at the end of every learning session suggested that the advantages in using the Guided Discovery system over a lecture presentation of the same material was that the learner dictates the pace.

It was also found that some learners would cram lessons, not exploring the lower levels of Guided discovery material, even if the system advice suggested that they do so. Those who reported that they did this ‘cramming’ of as much material as possible followed the material in a linear manner. Reading it lesson by lesson, section by section; without exploring level 2 and level 3 guided discovery steps even when getting incorrect answers. The written exam scores illustrated that they scored similarly to those who did not finish the lessons. Therefore those who completed lessons, and followed the lower levels of guidance, tended to achieve as highly as those who ‘sped’ through the lessons. These initial findings suggest that because they worked through the further explanation sections of the material, they gained a clearer understanding of material that they previously had not.

A preliminary result is that if those who failed the online test followed on by exploring the relevant. Further explanation sections immediately, then there would be a greater
likelihood that the misconception could be addressed. For such a fundamental part of the subject area it is essential that learners grasp the earlier concepts before proceeding further. The benefit is that most learners would grasp the basic principles, before progressing onto more complex material. Hence the sacrifice in learner control would seem to be worth it in terms of correcting the learners knowledge of basic tenets of the subject domain.

9.4 Evaluation Methodologies

Specific evaluation models have been investigated that are most likely to be applicable to the context of educational research. These models are used to determine the approach used to study the event that is of interest (Knussen et al., 1991). The evaluation models are in some respects interconnected and may adopt methodologies from one another. They are divided into six categories: the political model, the experimental model, the research and design model, the illuminative model, the case-study and the "teacher as researcher" model.

Apart from the "teacher as researcher" model and the political model, the others will be discussed further. The "teacher as researcher" model involves the teacher observing classroom practice in relation to innovative teaching strategies. This model has been criticised for possible subjectivity bias and role conflict in carrying out data collection. The political model focuses on the effects of innovative teaching on cultural values and quality of life. Both these models were regarded as unsuitable for providing the required appraisal in this research. These areas are undoubtedly influential in affecting learning, and are discussed as part of Mosston and Ashworth's (1990) anatomy of teaching styles (see chapter 4), but they remain out of the scope of this project.

9.4.1 The Experimental Model

In the experimental model the researcher manipulates a stimulus or input variable to determine if it produces response changes on the part of a group of subjects. The experimental method allows for cause-and-effect statements. In educational psychology the independent variable contains all of the following: (a) some form of
stimulus that is presented to the subjects, (b) the presumed causal part of the cause-and-effect relationship, (c) and experimenter control during the experimental process. Results obtained from using this method have been criticised for not being generalisable to the larger student population, or for the classroom where the learning takes place; hence not capturing the complexity or richness of classroom interaction.

9.4.2 The Research and Design Model

This could be regarded as being less controlled, taking an applied approach which moves the experiment out of rigidly-controlled laboratory conditions. This model uses a controlled version of the innovative teaching strategy that the researcher is interested in, using clear measurable objectives. A level of control over situational variables is implemented.

A criticism of this approach is that it has been designed to only measure factors which are directly amenable to non-ambiguous behavioural testing rather than looking at the plethora of factors that affect the learning environment. Neither does this model account for individualistic differences such as attitudinal and motivational traits.

Both the experimental model and the research and design model suffer from the same criticism of being removed from the qualitative aspect of the teaching process. To take the behaviour and reduce the results into a quantifiable form, assessing learners by using predominantly psychometric testing. Therefore there will be very little data on how learners themselves perceive the changes caused by innovative teaching strategies. Whether the findings can be scaled up and made applicable to real-life situations remains questionable.

9.4.3 The Illuminative Model

This approach for evaluation investigates teaching in its natural setting with little external interference. The presence of the researcher, collecting data in an overt manner, is intentionally kept at a low level to reduce any interference in the teaching
process. Control over situational and personal variables are kept to a minimum and the
data collected is usually qualitative in nature. A mixture of data-collection methods
can be used consisting of psychometric testing, unstructured interviews and video
recording for post-experimental analysis.

Because this data is predominantly qualitative it remains difficult to analyse in a
structured manner, and may be used to supplement quantitative methods, to provide an
overall description of the effects of the teaching. The methods used in this model may
be afflicted by the 'Hawthorne effect', where the presence of the researcher can
influence the behaviour of the subjects being studied (Radford and Govier, 1987).
Again there are criticisms over the generalisability of the results, and a reliance on the
accuracy of interpretation carried out by the researcher.

9.4.4 The Case-Study Model

This model uses the illuminative model to specifically provide an understanding of
situational and personal factors. Case studies rely on the interpretative ability of the
researcher and have been criticised for being non-systematic, relying too much on the
researcher to determine what is of significance. These types of results may be difficult
to generalise to other situations.

9.5 Evaluation Techniques

Evaluation techniques are concerned with gathering results from the innovation,
whether learning success is measured in terms of knowledge gains or individual verbal
responses. The major types of techniques for carrying out evaluation will be discussed
to explain the particular methodologies used in this experiment.
9.5.1 Observations

This is used predominantly in the illuminative model where the researcher would note changes caused by the introduction of the new teaching strategy into a natural setting. Observations should ideally be used for events that require minimal interpretation and may involve several observers examining the same episode to minimise qualms over reliability. Observation can also be used in controlled experimental conditions and may alleviate some of the criticisms which qualitative-type studies have received. A common criticism that arises is whether data collected is applicable to another setting. But this method could be seen as almost replicating the type of research that a classroom teacher would do, offering a realistic view of what is happening in an everyday setting. For example, Piaget (1957, 1965) extensively used observation in his work, collecting data from observations of children in natural settings such as homes and schools.

9.5.2 Psychometric Tests

Psychometric tests are used in experimental, research and design models to measure psychological characteristics such as intellectual ability or capacity. They are used to measure performance before and after exposure of the teaching innovation to the subject population. The data is usually quantitative in nature. Performance can be measured using tools such as multiple choice questionnaires and open-ended questionnaires. A possible difficulty is in determining the scoring of the replies and the design of the questions.

9.5.3 Self-Reporting Measures

Used in the research and design model, the learner provides the data that is required. A mixture of questionnaires and attitudinal measures provide more comprehensive information. A major problem of questionnaires is that subjects may try to fill in the questionnaire in such a way as to give the most favourable impression of themselves.
Some questionnaires such as the Eysenck Personality Inventory (Eysenck and Eysenck, 1969) try to overcome this problem by introducing into the questionnaire certain questions which will show this response bias if it is operating; but this works only to a limited extent. In spite of this and other drawbacks, the questionnaire method of assessing learning continues to be widely used due to the advantage of collecting large amounts of data in a very limited time-scale.

9.5.4 Interview

This is used in the illuminative model for collecting data. Interviews are carried out for different reasons but the purpose of the majority of them is to understand and assess the learner. The danger is that an interviewer may read into a person's report what is expected to be there. This can partly be overcome by making the interview more structured and providing extensive interviewer training beforehand. Interviews are useful for open-ended type replies where the interviewer is able to probe deeper into the answer that the respondent has given, something that is more complex using a questionnaire. But it is difficult to re-run an interview. Other attempts to make the interview less subjective and more open to scrutiny includes tape recording interview sessions or methods of content analysis of the verbal report. This method operates by the researcher constructing categories and counting the amount of verbal behaviour which falls into each. Even a relatively structured interview is subject to bias and analysis of data requires a longer period to complete.

9.5.5 Automated Measures

These methods collect data automatically. A history file is usually activated in response to the learner carrying out the experiment, providing quantitative data about information such as navigation of web pages, mouse clicks and requests for help. These provide little information on motivational and situational factors that have determined the actions. The focus is on measuring behaviour, rather than explaining it.
9.6 The Evaluation Strategy

Discussion has centred on evaluation models that may be applicable, including descriptions of possible tools that can be used to gather data on learning. This section will outline the selection of certain methods, and the reasons for this.

When determining the most suitable method there needs to be a consideration of what is being studied and how it can be measured. In earlier chapters (2 and 3) many methodologies have been used to gather information on learning using computerised environments. With some of these studies, the data is a mixture of qualitative and quantitative data. Kirakowski and Corbett (1990) proposed certain characteristics that can help determine which evaluation methodology should be chosen. There should be a conceptualisation of what the target area under investigation is, how the subject matter is to be studied and techniques for analysing the collected data.

In determining which model and research techniques are suitable there needs to be an evaluation of the aims and objectives of the experiment, the context in which it will take place and the purpose for carrying it out. If the approach is more objective and specific, the resultant technique should also reflect this. For example illuminative studies can be ideal for carrying out an investigation encompassing situational and motivational factors within a classroom setting. Automated measures could be useful in an experiment collecting quantitative data on frequently accessed web pages where there maybe less requirement to explain the reason why in situations where there is no control over learner behaviour.

In this project, the evaluation model and techniques used for assessing the research hypothesis was the research and design model. Although less formal than the experimental model it allows a more comprehensive and wide-ranging investigation of the behaviour that is of interest. Psychometric tests and self-reporting measures provided a specific form of data concerning knowledge gains and satisfaction with the system. This information was further supported by an analysis of the learners navigational files collected automatically by the system and a semi-structured interview administered immediately after the experiment. Therefore there is a mixture of both
qualitative and quantitative data; with the use of self-reported, interview and automated techniques for data collection.

The research and design model was used because of a need to measure differences for several specific dimensions; from satisfaction with the system to learning styles and learning outcome for individual subjects. A quantitative assessment was gained from an analysis of the user satisfaction questionnaire. These findings were expanded further by the use of a semi-structured interview which provided a more qualitative expanded dimension to the answers given. This would provide a more in-depth understanding of why some users were more satisfied with the use of certain versions of the system while others using the same version may not be so satisfied. Asking a question and then following on, if the reply is of interest by asking further questions, may provide an explanation of why the learner behaved in a particular manner.

Psychometric tests and self-reporting measures provided formalised, easily collated numerical data. With the learning style questionnaire this would allow the experimenter to quickly filter the subjects into the relevant experimental conditions. Using the pre and post-test approach meant that those who had too much knowledge about electronic logic could be rejected immediately. Therefore it could be assumed that subjects began with approximately the same amount of knowledge about the topic, suggesting that any improvements in learning this topic would be the result of exposure to a particular experimental condition. Carrying out a post-test meant that knowledge gains could be quantitatively measured. This could be analysed in relation to any possible interaction with learning styles and user satisfaction with the different conditions.

With the adoption of the experimental approach and methodologies outlined earlier in this section, the data would allow an investigation of three main hypothesis: (a) an environment based on guided discovery would lead to gains both in user satisfaction and learning outcome, (b) that the embedding of a cognitive tool would enhance the effect of the guidance, (c) the learning style of the subject would not hinder the satisfaction or learning outcome of the learner.
9.7 The Research Methodology

The study measured the interaction between different levels of guidance and learning style. The following sections (overleaf) describe the general research questions, likely experimental outcomes, selection of subjects, and measurement methodologies for measuring learning outcome and user satisfaction levels.
9.7.1 General Research Questions
Three research hypotheses were investigated: (a) Do different levels of guidance, with the inclusion of cognitive tools, influence learning outcome or user satisfaction? (b) Does learning style affect either learning outcome or user satisfaction? (c) Are there any interaction effects between learning styles and levels of guidance that influence either learning outcome or user satisfaction? These all relate to WWW hypertext systems for learning. The research hypothesis was investigated by analysing and measuring gains in learning outcome, and then examining user satisfaction scores.

9.7.2 Predicted Experimental Outcomes
It is suggested that the guided discovery condition and the concept mapping condition will produce higher gains in learning than the unguided condition. It is predicted that learners with different learning styles will perform no worse with the guided discovery system than the other systems. In terms of interaction effects it is predicted that guidance will produce better results when integrated with concept maps. Irrespective of the learning style, there will not be degradation in learning outcome and user satisfaction. For example, learners with different learning styles will show a general improvement in learning using the guided discovery approach in comparison to their counterparts in the map only and unguided conditions.

The sample size of the study is important in terms of its implications for validity and reliability. It is possible to estimate sample size systematically to determine its ideal value. The aim is to determine whether an effect is statistically significant, and if it is due to the variables manipulated in the experiment only. Using Odeh and Fox's (1991) method for calculating sample sizes, a sample size of 30 gives a power in excess of 0.9, for detecting a difference between the two group means of one standard deviation.

9.7.3 Subject Population and Assignment to Experimental Conditions
84 paid university students, selected from a broad spectrum of courses, were assigned to one of three groups according to their learning style. Students completed a pre-test containing questions about different parts of electronic logic, to ascertain previous knowledge about the topic. Those subjects who exhibited over-familiarisation with the subject material were rejected. This use of a pre-test to filter the sample ensured that
all subjects in the separate conditions were at the same level of understanding. There was an approximate representation of each of the learning styles for the three conditions.

The Learning Style Questionnaire (LSQ) was administered after the subjects were considered eligible to participate in the experiment. This analysis employed the scoring from Honey and Mumford’s study (1982), to determine the learning style of each subject. They were then subdivided into one of four dominant learning styles and assigned to one of three conditions based on these scores: a guided discovery system, a map only system and an unguided system. The number of subjects in each condition were 28 respectively. The groups were selected to produce a sample that was evenly matched in terms of learning styles and background knowledge of the topic. No check was made for controlling the male-to-female ratio, although the selection produced similar male-to-female ratios. Hence sex differences were included as a subsidiary hypothesis.

The size of the groups in each condition were the same although there were slight differences in composition based on different learning styles. The statistical tests used to analyse differences between the conditions are discussed in chapter 10, Analysis of Evaluation Data.
The assignment of subjects based on learning styles is summarised as pie charts. Figure 16 below displays the amount of students according to learning styles for the guided discovery condition, the map only condition and the unguided condition. Note: Total sample per condition = 28.

Figure 16:

The distribution of learners for Condition A (Guided Discovery System)

The distribution of learners for Condition B (Map only system)

The distribution of learners for Condition C (Unguided System)
Each subject was allocated 60 minutes to work through the material to be learnt. A further 30 minutes was given to answer the exam, user satisfaction questionnaire and a brief interview. This would provide both quantitative data in the form of scores for learning outcome and user satisfaction levels, as well as qualitative data on the opinions of the subjects about the conditions. In total, 90 minutes were allocated to the total learning and testing session for all three conditions. Those subjects in the guided discovery condition and the map only condition were given additional questions related to the concept map tool. All subjects received an identical exam.

The electronic logic material was at an introductory level for subjects who had no previous knowledge of Electronics. Only the post-test results were collected for statistical analysis as it was regarded that the pre-test results would show subjects to have the same minimal amount of knowledge.

9.7.4 Pilot Study
In the pilot study phase, 10 subjects were selected, ranging from learners who had previously attended a course on electronic logic to those who had no previous knowledge of this area. The aim of the pilot study was to ascertain, using a small sample, whether the experimental conditions needed modification or refinement before commencing with the main experiment.

The evaluation of the experimental conditions is twofold. The first part of the evaluation was to determine the learning aspect of the experiment. The second part could be regarded as the 'nuts and bolts' of the system, consisting of design questions such as the interface to the learning environment and its operation during the different experimental conditions.

Self-administration of the LSQ prior to the experiment, was favoured so that the sample population could be allocated equally according to learning styles, to each of the experimental conditions. In terms of the amount of material which the learner is expected to work through, the pilot study suggested that the majority of learners, regardless of their learning style, would reach lesson four and most probably reach
Lesson 6 in the time given. The length of time, which should be allocated to the total learning session was found to be sixty minutes. The total time allocated to work through the material was derived from the feedback given by the pilot study. Any time less than sixty minutes, would mean that the learner would only grasp the 'foundation' principles of Electronic Logic. Longer than an hour would suggest that the learner would become tired, with some reporting being overwhelmed by the amount of information which had to be assimilated. The exam, user satisfaction questionnaire and interview would be administered immediately after using the system.

The wording of the paper and the type of questions that were set, to be able to measure the understanding of the subject, were piloted on staff in the Computing Department. A Departmental Lecturer provided constructive feedback on the exam paper. After some minor changes to some of the possible answers that the subject could select and some modification of the wording, it was given to subjects in the pilot study for further testing. Their comment on the time taken was that a minimum of 20 minutes to a maximum of thirty minutes was adequate to answer as many questions as possible.

The value of including online testing was also preliminarily assessed during the pilot study phase. The most adequate and efficient way to measure the answers was to provide a multiple choice section at the end of certain lessons with the expectancy that this would both reinforce learning and allow the learner to measure self-progress. The response from the subjects for this feature in the pilot study was highly positive.

In terms of the operability of the system the results of the pilot study showed that the system was fairly intuitive to use and required no steep learning curve. Those who had no previous knowledge of how to operate an Internet browser would, within minutes of being shown the basic clicking of a hypertext link, be able to adequately operate the system in any of the three conditions.

In terms of the advice given in the Guided Discovery Condition, the pilot study sample investigated the level, quantity and type of advice in the Guided Discovery condition.
and the Conceptual Map condition. It was found that it was adequate for the material that was being presented.

The Guided Discovery condition and map only condition required the addition of a cognitive tool, the Concept map. With the evaluation of the Concept map, questions centred on the actual structure of the maps and also its appearance. There was agreement that the Concept maps were reflective of the concepts and theories displayed in each of the lessons.

The screen estate given by the designer to the Advice window in part determined the size of the Concept maps. Because the maps varied in size it was difficult to determine an the ideal size. The compromise reached meant that the user would have to scroll vertically and horizontally to view a minority of the maps. In summary the Concept maps provided a valid representation of the conceptual framework of the particular lesson. The concept labels were meaningful in that they illustrated the relationship between concepts; each map could inform the subject which concept was to be encountered next providing a conceptual readiness to work through the next section.

In conclusion, the pilot study highlighted changes in the areas of testing, the procedure itself and the operation of the system, feedback from the pre-test exam and time duration allocated to the learning session were all examined; while the value of the online testing was supported and the operationability of the system was at the correct level. Areas such as the efficacy of the advice, the value of the map and the use of different levels of guidance were further investigated in the main experiment. The pilot study offered some useful revisions to the operation of the system and the procedures involved in carrying out the experiment, as well as providing some preliminary theoretical strands about what to observe in the main experiment.

9.7.5 Measurement Methodologies
The pre-test exam was designed to measure knowledge of the subject domain prior to carrying out the experiment. If knowledge was at a very basic level, or in most cases non-existent, the Learning Style Questionnaire (LSQ) would be administered. The LSQ, designed by Honey and Mumford (1982) was used to provide a dominant style
from the four main styles of learning. The LSQ has been fully discussed in chapter 8, with the explanation of each of the learning styles. Its relation to other types of research on learning styles was also discussed and the LSQ is included in Appendix A with the relevant marking scheme. Therefore it will only be briefly summarised below.

Honey and Mumford view learning styles as divisible into four categories: Activist, Reflector, Theorist and Pragmatist. Within each style is a ranking ranging from a very strong preference to a very low preference for each learning style. Hence for example a learner could have a strong activist score and score very low for the theorist scale, hence making the dominant learning style one of activist. It is suggested that there is a relationship between learning styles and learning activities, with certain learning styles benefiting most from specific activities. The assumption is that there are activities congruent with each of the four learning styles. Therefore if the educator is able to determine the individuals' learning style then activities can be created which may meet these needs, or the learner can select tasks which suit this particular style of learning. The LSQ allows the learner to be categorised into a dominant learning style and hence predictions made about possible benefits with providing learning activities consonant with that prevailing learning style. The purpose of the use of the LSQ in this experiment is to ascertain the subjects learning style and then determine if this preference for specific learning tasks is detrimentally affected by the guided discovery condition.

Learning outcome scores were measured with the administration of an 18-item examination based on the electronic logic material. This exam provided an overall score. The questions on the exam were structured to assess the understanding of key concepts and their application in solving the problems set. The questions, related to the understanding of conceptual material, involved the subject providing a written solution. Those related to problem solving involved the learner providing a step-by-step solution. The exam and its relevant marking scheme are included as Appendix B. The aim of the test was to determine the increase in knowledge gain (learning outcome). The exam marking was carried out with the removal of the user ID, hence anonymity of the user's identity, reducing the possibility of experimenter bias.
A questionnaire was administered after the examination to assess the satisfaction of the learner with the system being used. Statements were in the form of a likert-type scale with the learner marking a reply along the spectrum ranging from strongly agree to strongly disagree. The total of 38 items centred on five issues: (1) system satisfaction, (2) navigation, (3) system design, (4) advice, and (5) concept maps. Questions concerning concept maps were not included in the unguided condition. The user satisfaction questionnaire is included in Appendix C1. The aim of the questionnaire is to ascertain the level of satisfaction experienced with using the system, and whether there is any interaction between this, learning outcome and learning style.
9.8 Summary

This chapter on research evaluation strategies has outlined evaluation requirements, methodologies to evaluate learning behaviour, and techniques to gather data. This was followed by a discussion of methods used to measure knowledge gains and learner satisfaction.

The research and evaluation model was selected as the most suitable for the factors under investigation; the interaction between learning outcomes, satisfaction levels and learning styles in relation to a guided discovery, map only and unguided conditions.

Psychometric tests, questionnaires and interviews were regarded as the most appropriate for measuring learning outcome and learner satisfaction. The Learning Style questionnaire was used to determine the dominant learning style of the learner, and to assign the learner to a particular experimental group.

Descriptions of the stages of the experiment were given, with results of the pilot study providing predicted results. The evaluation model and subsequent techniques will allow an investigation into guidance and learning using both quantitative and qualitative techniques.
Chapter Ten

Results

10.1 Introduction

This chapter examines the results, presenting trends in the statistical data and their significance. The aim is to investigate whether the provision of guidance will have an influence on learning outcome and user satisfaction. An examination is also made of the effect of learning style on these results. The statistical analysis concentrates on differences between a guided discovery condition, map only condition and an unguided condition.

The methods used to collect the data are described in chapter 9. The implications of these results are discussed in chapter 11. A discussion of navigational log files and interview feedback are included in the Discussion (Chapter 10). The statistical package used is Microsoft Excel (Microsoft Office 97).

The techniques used to manipulate the data into an analysable form were single factor ANOVA and t-test. For this research, a significance level of 0.05 was used unless specified. The conditions are described as the following:

- Condition A - guided discovery condition
- Condition B - map-only condition
- Condition C - unguided condition (Control)

These conditions are collectively referred to as different methods of guidance or Guidance Method.

10.2 The Research Issues Stated as Statistical Hypotheses (H₀)

The three research hypotheses are represented as statistical hypothesis below:
• Guidance Methods
There are no differences between the means of learning outcome scores or user satisfaction levels, among the different methods of guidance. Guidance Method is analysed as a main effect in an ANOVA analysis.

• Learning Style Differences
There are no differences between learning outcome scores or user satisfaction levels, among the different learning style groups of subjects. Learning style differences are analysed as a main effect in an ANOVA analysis.

• Interaction Effects
There are no interaction effects between learning style and guidance method in their effect on learning outcome scores or user satisfaction levels. The interactions between learning style and guidance method are analysed as the interaction effect in an ANOVA analysis.

• Sex Differences
There are no sex differences in learning outcome scores, among the different methods of guidance. Sex differences are analysed as a main effect in an ANOVA analysis. This is a subsidiary hypothesis.

10.3 Analysis on the Satisfaction Variables

The User Satisfaction questionnaire was divided into five issues, which examined particular features of the systems in the guided, map only condition and unguided condition (see appendix C for the questions related to each of the issues).

In the satisfaction questionnaire, the students were asked their opinion about 5 areas, using a total of 38 items:

1. System satisfaction (consisting of 8 Questions)

2. Navigation (consisting of 9 Questions)
3. System design (consisting of 2 Questions)

4. Advice (consisting of 13 Questions)

5. Maps (consisting of 6 Questions)

10.4 Analysis Methodology
Each of the research hypotheses is tackled in turn. The table 1 below provides a summary of the variables used in the analysis.

<table>
<thead>
<tr>
<th>Experimental Variables:</th>
</tr>
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<tbody>
<tr>
<td>A: Guided Method</td>
</tr>
<tr>
<td>1. Guided Discovery System</td>
</tr>
<tr>
<td>2. Map only system</td>
</tr>
<tr>
<td>3. Unguided System</td>
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<table>
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<tr>
<th>B: Learning Style</th>
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</thead>
<tbody>
<tr>
<td>1. Activist</td>
</tr>
<tr>
<td>2. Reflector</td>
</tr>
<tr>
<td>3. Theorist</td>
</tr>
<tr>
<td>4. Pragmatist</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependant Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Learning Outcome score</td>
</tr>
<tr>
<td>B: Subjective feedback (subdivided into 5 issues)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1. System satisfaction</td>
</tr>
<tr>
<td>2. Navigation</td>
</tr>
<tr>
<td>3. System design</td>
</tr>
<tr>
<td>4. Advice</td>
</tr>
<tr>
<td>5. Maps</td>
</tr>
</tbody>
</table>

Table 1 – Variables for Analysis
10.5 Learning Outcome and User Satisfaction Scores

The learner's scores in the exam were used to assess learning outcome. User satisfaction with the conditions was assessed using a 38 item self-administered questionnaire. Satisfaction issues refer to the 5 issues referred to in the above table. The Unguided condition (control) did not receive questions pertaining to maps because they did not have this facility, hence the analysis for map satisfaction was carried out between guided and map only conditions.

Each of the hypotheses was addressed in stages:
(1) Learning outcome was analysed in terms of a comparison between the Guidance Methods.
(2) Learning outcome was analysed in terms of a comparison between the Learning Styles.
(3) Learning outcome was analysed in terms of a comparison between sex differences and the Guidance Methods.
(4) Overall user satisfaction in terms of a comparison between the Guidance Methods.
(5) User satisfaction divided into satisfaction issues, and analysed in terms of comparison between Guidance Method.
(6) User satisfaction compared to Guidance Method and satisfaction issues.

The learning outcome score means are given, along with the number of subjects in each group and the standard deviation. These are summarised and presented as tables in the remainder of this section.
Table 2 - Overall Exam Score Comparison (Learning Outcome)

Results of the exam in all three systems. Equal amounts of Activists, Pragmatist, Theorists, Reflectors were divided into each condition.

The level of significance was set at \( p<0.05 \) or \( p<0.000 \).

<table>
<thead>
<tr>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>52.19</td>
<td>37.34</td>
</tr>
<tr>
<td>S.D</td>
<td>17.189</td>
<td>12.55</td>
</tr>
<tr>
<td>SEM</td>
<td>3.308</td>
<td>2.41</td>
</tr>
</tbody>
</table>

Values are means, SD and S.E.M,
No of samples n=28

Result: Statistical differences were found (using the ANOVA statistical analysis) between the Condition A and B (at \( p<0.05 \)); Condition A and C (at \( p<0.05 \)). No differences were found in Condition B and C.
Table 3 – Overall Exam Score Comparison between Guided Methods (Learning Outcome)

Results of learning outcome in all three systems. The results of each type of learner were compared for each condition.

The level of significance was set at \( p < 0.05 \) or \( p < 0.000 \).

<table>
<thead>
<tr>
<th>Type</th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activist</td>
<td>42.36 ± 5.71</td>
<td>34.61 ± 4.577</td>
<td>30.99 ± 4.18</td>
</tr>
<tr>
<td>Theorist</td>
<td>44.32 ± 0.80</td>
<td>43.56 ± 7.46</td>
<td>31.06 ± 5.46</td>
</tr>
<tr>
<td>Reflector</td>
<td>65.34 ± 3.56</td>
<td>38.74 ± 4.02</td>
<td>36.08 ± 5.34</td>
</tr>
<tr>
<td>Pragmatist</td>
<td>46.21 ± 8.13</td>
<td>39.78 ± 1.60</td>
<td>40.91 ± 6.42</td>
</tr>
</tbody>
</table>

Values are means and S.E.M,

No of samples: Activists = 12, Theorists = 3, Reflectors = 10-12, Pragmatists = 2-3

Result: Statistical differences were found (using the ANOVA statistical analysis) for theorist learners between the Condition A and C (at \( p < 0.05 \)); for Reflectors between Condition A and B (at \( p < 0.05 \)) and Reflectors between Condition A and C (at \( p < 0.01 \))

No differences were found for Activists or Pragmatists in any of the conditions.
Table 4 – Overall User Satisfaction Comparison between Guided Methods (User Satisfaction)

Results of the satisfaction scores (%) in all three systems. The results of each learner style were compared for each condition.

The level of significance was set at \( p < 0.05 \) or \( p < 0.000 \).

<table>
<thead>
<tr>
<th></th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activist</td>
<td>46.27 ± 3.95</td>
<td>42.98 ± 3.75</td>
<td>37.79 ± 5.7</td>
</tr>
<tr>
<td>Theorist</td>
<td>51.75 ± 12.38</td>
<td>39.47 ± 3.22</td>
<td>50.8 ± 8.59</td>
</tr>
<tr>
<td>Reflector</td>
<td>53.15 ± 5.62</td>
<td>49.76 ± 3.96</td>
<td>55.48 ± 2.36</td>
</tr>
<tr>
<td>Pragmatist</td>
<td>48.24 ± 2.84</td>
<td>73.68 ± 0</td>
<td>67.10 ± 1.86</td>
</tr>
</tbody>
</table>

Values are means and S.E.M,

No of samples: Activists = 12, Theorists = 3, Reflectors = 10-12, Pragmatists = 2-3

Result: No statistical differences were found (using the ANOVA statistical analysis) in any of the conditions.
Table 5 – Overall User Satisfaction divided into Satisfaction Issues between Conditions

Results of the percentage satisfaction factor in all three systems.

<table>
<thead>
<tr>
<th>Satisfaction Issues</th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction</td>
<td>47.32 ± 5.03</td>
<td>44.64 ± 5.86</td>
<td>54.46 ± 3.36</td>
</tr>
<tr>
<td>Navigation</td>
<td>52.85 ± 5.04</td>
<td>54.28 ± 4.07</td>
<td>60.71 ± 3.76</td>
</tr>
<tr>
<td>System Design</td>
<td>46.42 ± 9.03</td>
<td>48.21 ± 3.38</td>
<td>60.71 ± 9.03</td>
</tr>
<tr>
<td>Advice</td>
<td>54.94 ± 3.93</td>
<td>48.62 ± 3.10</td>
<td>56.86 ± 3.79</td>
</tr>
<tr>
<td>Maps</td>
<td>32.73 ± 9.11</td>
<td>35.11 ± 5.47</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>49.53 ± 2.71</td>
<td>47.46 ± 2.66</td>
<td>58.03 ± 3.04</td>
</tr>
</tbody>
</table>

Values are means and S.E.M,
No of sample = 28
Result: No statistical differences were found (using the ANOVA statistical analysis) for any of the Conditions.
Table 6 – Comparison of User Satisfaction Issues between Conditions

Table 6 shows the statistical comparison between conditions A and B, condition A and C, Condition B and C. A t-test analysis of satisfaction scores (satisfaction, navigation, system design, advice and maps) were compared.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Statistical Analysis with Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comparisons between Conditions A (Guided Discovery Tutoring) and B (Map only condition)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P value</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>0.35</td>
</tr>
<tr>
<td>Navigation</td>
<td>0.40</td>
</tr>
<tr>
<td>System Design</td>
<td>0.46</td>
</tr>
<tr>
<td>Advice</td>
<td>0.10</td>
</tr>
<tr>
<td>Maps</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>Comparisons between Conditions C (Unguided Discovery) and B (Map only condition)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P value</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>0.07</td>
</tr>
<tr>
<td>Navigation</td>
<td>0.11</td>
</tr>
<tr>
<td>System Design</td>
<td>0.28</td>
</tr>
<tr>
<td>Advice</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Comparisons between Conditions A (Guided Discovery Tutoring) and C (Unguided Discovery)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P value</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>0.11</td>
</tr>
<tr>
<td>Navigation</td>
<td>0.07</td>
</tr>
<tr>
<td>System Design</td>
<td>0.27</td>
</tr>
<tr>
<td>Advice</td>
<td>0.19</td>
</tr>
</tbody>
</table>

NS=not significant, S=significant

Result: No significant difference was found between conditions A and B (for satisfaction, navigation, system design and advice), between conditions B and C and between conditions C and A.
Table 7 – Analysis of Correlation between Overall User satisfaction and Exam Result

Results of the learning outcome (%) and satisfaction scores (%) in all three systems. Equal amounts of Activists, Pragmatist, Theorists, Reflectors were equally divided into each group.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Exam result (%)</th>
<th>Satisfaction Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>52.19 ± 3.30</td>
<td>49.53 ± 2.71</td>
</tr>
<tr>
<td>B</td>
<td>37.34 ± 2.41</td>
<td>47.46 ± 2.66</td>
</tr>
<tr>
<td>C</td>
<td>33.89 ± 2.78</td>
<td>48.87 ± 3.04</td>
</tr>
</tbody>
</table>

Values are means and S.E.M, No of samples n=28

A correlation coefficient analysis was carried out for learning outcome and satisfaction to determine any relationship.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Correlation R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-0.3879</td>
</tr>
<tr>
<td>B</td>
<td>-0.03433</td>
</tr>
<tr>
<td>C</td>
<td>-0.49984</td>
</tr>
</tbody>
</table>

Df = 26

Result: No correlation was found between user satisfaction and learning outcome. All the subjects were satisfied using either learning method, although there is a higher exam score in Condition A.
Table 8 – Comparison of Sex Differences for Learning Outcome

Results of the learning Outcome in all three systems. Sex differences were compared within each condition. Males and females were compared for each condition. The level of significance was set at $p < 0.05$ or $p < 0.000$.

<table>
<thead>
<tr>
<th></th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>53.71 ± 4.78</td>
<td>37.88 ± 2.82</td>
<td>31.36 ± 3.41</td>
</tr>
<tr>
<td>Females</td>
<td>50.44 ± 4.86</td>
<td>36.05 ± 5.14</td>
<td>37.40 ± 5.57</td>
</tr>
</tbody>
</table>

Values are means and S.E.M,
No of males =15-17
No of females = 11-13
Result: No statistical differences were found (using the ANOVA statistical analysis) for any sex differences. For both sexes, statistical differences were found between Condition A and B, Condition A and C (at $p<0.05$).
These trends in the data are represented in the profiles of:

Figure 17 Overall Satisfaction of Conditions A, B and C

![Overall Satisfaction Graph]

Figure 18 System Satisfaction of Conditions A, B and C

![System Satisfaction Graph]
Figure 19 Navigation scores of Conditions A, B and C

![Graph showing navigation scores for Conditions A, B, and C.]

Figure 20 System Design Satisfaction of Conditions A, B and C

![Graph showing system design satisfaction scores for Conditions A, B, and C.]

Figure 21 Advice Satisfaction of Conditions A, B and C

Figure 22 Map Satisfaction of Conditions A and B
Chapter Eleven

Analysis and Discussion

11.1 Introduction

The research area investigated is the provision of guidance for a hypertext learning environment based on the Internet. Guided Discovery Learning has been cited as the educational pedagogy both in the design of the material and also in the system interventionist strategies used. Therefore this approach has been used to investigate the provision of a guiding process in Discovery Hypertext learning environments for the Internet. This chapter examines the effectiveness of this strategy for promoting learning in the light of the results collected. The research issues are reiterated, with an outline of the research methodology used to gather the results. This is followed by conclusions derived from the statistical analysis. A discussion of these conclusions in relation to the field of hypertext and learning on the WWW is carried out in chapter 12.

11.2 The Research Hypotheses

The underlying principles of this research have centred on Guided Discovery Learning as an educational pedagogy able to provide the support that the learner requires for hypertext-based discovery learning. Although there have been several research aims in this thesis, these issues have been interconnected in the investigation of this educational approach.
To investigate specific factors that would affect learning such as: (1) the lack of individualisation of domain material for learning and (2) disorientation when navigating across the information space. Past research has advocated the structuring of hypertext and system control over the learning process as possible solutions. A key part of this research has been to investigate whether a learning environment, containing a tutoring element based on a specific pedagogy, would result in greater gains in learning and satisfaction than a non-adaptive hypertext environment. The use of knowledge-based approaches has generally drawn mixed conclusions with no established guidelines for the design of such systems. Concept design strategies were rarely used in the design of the material, nor was there the implementation of sequences of discovery steps to mediate the teaching process.

A first hypothesis in this thesis is that the use of a guided discovery approach will allow a high degree of learner freedom and decreased levels of system intervention. This can be characterised as a shift from a traditional strong reliance on user modelling or AI techniques, to one based on some of the components of a ‘minimalist’ Intelligent Tutoring system. Advice is adapted during the learning process, with varying levels of system guidance both at the macro level (hyperdocument) and at the micro level (within the steps of the discovery process). This guidance is provided in terms of advice displayed in the Advice frame, system control over the navigation buttons and the switching on and off of hypertext links (Brusilovsky, 1995) in relation to the student’s progress through the domain material.

Although there has been research into the design of hypertext systems for learning these systems continue to be experimental, lack quantitative data and rely on less formal investigative techniques to collect this data. The results collected from this thesis have been derived from a formal approach using statistical data for gauging learning outcome and user satisfaction; with further analysis of responses using a semi-structured interview. The sample size, coupled with the selection of subjects using measures to ascertain past domain knowledge and a tool for assessing learning style, has produced a more statistically representative sample from which to derive conclusions.
The second hypothesis is that cognitive tools, in particular concept maps, can enhance the Guided Discovery process. Use of the cognitive tool without the guided discovery element is predicted to be less effective. Concept maps are a schematic device for representing a set of concept meanings embedded in a framework of propositions. These act as an explicit representation of the author's (expert's) knowledge, focusing on concepts and the meaningful relationships between them. The main functions of Concept maps are that: (1) it is made clear for the student the key ideas needed to solve a specific learning task, (2) as an advanced organiser supporting the relation of new knowledge to existing knowledge, and (3) as a 'visual roadmap' for user orientation when traversing from node to node.

In terms of learning, a concept map is regarded as a tool able to help students learn about metaknowledge and metalearning (Novak and Gowin, 1984). The basic premise is that guided discovery will be enhanced by the addition of this cognitive tool. The simultaneous provision of guided advice, a relevant concept map and a structured sequence of discovery steps will provide the cognitive scaffolding that is needed by the learner to overcome misconceptions. In comparison just adding a concept map tool to conventional hypertext will not promote as effective a meaningful learning experience, although it may be better than having no concept map at all (as in the unguided condition). Therefore an aim of this system was to combine the guided advice in a way which would support the benefits of a concept map tool. This was carried out by designing the material using an instructional strategy specifically geared for teaching conceptual knowledge. Which in turn was used to base the design of a network of hypertext nodes and links, the concept map and the size of the discovery steps (as illustrated in Figure 10, section 5.9.1).

Knowledge-based techniques were used in the design of the expert system module to determine the advice to be presented and to exert system control over the learner's navigation. Providing navigational support will help to alleviate the cognitive overload problem caused by learners not knowing where they are, where they have come from and where to go next; again assisting the learner in focusing on the knowledge domain (Conklin, 1987). This was not a strong use of artificial intelligence. Instead the adaptivity focused on using a system resembling sets of rules (similar to production
rules). It was suggested that this could be used to provide the level of individualistic tuition required.

The third hypothesis is that the learning styles of the student will not have an influence on the type of educational paradigm that is used. The suggestion is that Pragmatists, Theorists, Activists and Reflectors will be as satisfied using the guided discovery system as they would the map-only system and the unguided (conventional hypertext) system. Thus, providing evidence that the guided discovery learning paradigm can be used for many types of learning styles; at least as much as the unguided system can. That it is no worse to use, in terms of accounting for learning styles, than other types of learning environments.

The evaluation procedure involved the design and implementation of tests to measure learner satisfaction and supplemented by exam scores for knowledge gains (learning outcome). Coupled to this was an analysis of navigational paths as collected in the form of history files. This was especially important for determining whether subjects in the guided discovery condition accepted the system advice to follow discovery steps designed to overcome misconceptions detected from the online tests. The majority of learners who failed an online test would work through the lower levels of guided discovery related to the failed concept (as shown earlier in the pilot study results in section 9.3).

The research issues were: (1) would a Guided Discovery environment produce greater gains in learning outcome and satisfaction than an unguided environment? (2) are Concept maps more supportive in the Guided Discovery condition than use of the Concept map alone? (3) will the learning style of the learner influence the learning outcome or user satisfaction scores, according to whether the system provides guidance? The issue is therefore to examine whether the components used to provide the learner with guidance are effective in supporting learning from a WWW hypertext learning system. The dependent variables were: (a) learning outcome (an exam, to assess levels of knowledge attainment), and (b) learner satisfaction (measured using a satisfaction survey). The independent variables were: (a) the tutoring mode of the
system (guided or unguided), (b) the learning style of the student and (c) the addition of a concept map tool.

The methodology for the collection of data has been discussed in chapter 9 (Research Evaluation Strategy). The subsequent statistical analysis was carried out in Chapter 10. The re-iteration of the research issues and how these were measured were discussed in this section. The next section will discuss the findings in more detail to provide a basis for constructing general principles for learning, in chapter 12.

11.3 Experimental Conclusions

The learning outcome scores were used to determine the knowledge gain the subjects had achieved when exposed to different experimental conditions. This was used, along with a factor analysis carried out on the satisfaction questionnaire, to determine the overall effects of a guided discovery learning environment on satisfaction levels. The satisfaction variables were divided into five issues: (1) system satisfaction, (2) navigation, (3) system design, (4) system advice, and (5) concept map tool. A discussion of learning outcome will be followed by an examination of satisfaction issues, to determine any relation between learning outcome, learning style and the addition of guidance.

Learning Outcome:

1. The differences between the mean scores for learning outcome (knowledge gain) for the guided discovery, map-only and unguided conditions were statistically significant. This suggests that there was a difference in learning outcome according to the provision of guidance. The subjects in the guided discovery condition achieved a higher mean score (52.19 ± 3.3), and were significantly different from the map-only condition (37.34 ± 2.41). The map-only condition scored a higher mean than the unguided condition (33.89 ± 2.78), although not to a statistically significant level.
2. The mean scores for learning styles between the guided discovery, map-only and unguided conditions for learning outcome were statistically significant for theorists and pragmatists. This suggests that there was a difference in learning outcome according to guidance and certain learning styles. The Reflectors in the guided discovery condition (65.34 ± 3.56) scored a higher statistically significant score than the map only (38.74 ± 4.02) and unguided condition (36.08 ± 5.34). The Theorists in the guided discovery condition achieved a higher mean score (44.32 ± 0.8) and were significantly different from the unguided condition (31.06 ± 5.46), but not for the map only condition.

3. Sex differences were compared with each experimental condition in terms of learning outcome, with no statistical differences for any sex differences.

**Issues of Learner Satisfaction:**

1. General satisfaction with using the system, using a t-test analysis of satisfaction scores, was not statistically significant between the guided discovery condition, the map-only and unguided condition. There was no difference between the map-only and unguided condition. The guided condition did not seem to lead to a higher perception of satisfaction.

2. Navigation issues did not account for a significant difference between the guided discovery condition, than for the map-only and unguided condition. Therefore this suggests that the subjects in the guided discovery condition did not feel restricted by the navigational control exerted by the system, and felt levels of freedom to browse the hypertext material similar to the map-only and unguided condition. This suggests that the guided discovery condition subjects were not confused about the organisation of the hypertext domain, or about the actions of the navigational aids.

3. System design did not account for a significant difference in the satisfaction level for all 3 conditions. Therefore it was suggested that learners, regardless of the system being used, experienced similar levels of satisfaction with using the system. This may suggest that the layout of the frames and the reading of the material from the screen were not an obstacle to using the system in the guided condition.
4. Satisfaction with system advice was not statistically significant for the guided discovery, map-only and unguided condition. There was no difference between the map-only and unguided condition. This suggests that the provision of advice did not lead to higher dissatisfaction. Advice could be regarded as being supportive for helping to understand the material and for navigational support.

5. The concept map tool did not account for a significant difference in satisfaction. It appeared that the availability of a concept map did not affect satisfaction levels. This may lead to the conclusion that the concept map may not have been used either in understanding the material or for navigation. It should be recalled that this function was available in the guided and map-only conditions, but not the unguided condition. The possible explanation for this is given in section 11.4, Analysis of User Profiles and Interview Responses.

Learning Styles and Satisfaction

1. The differences in general satisfaction between learning styles were not statistically significant. In terms of preferred learning styles it did not seem to affect user satisfaction with learning from the discovery, map-only and unguided conditions.

2. Learning styles did not account for a significant difference in system satisfaction, suggesting that Pragmatists, Theorists, Reflectors and Activists were satisfied with learning material in all three conditions rather than a textbook or lecture as derived from the user satisfaction questionnaire.

3. Learning styles did not account for a significant difference in navigation issues. Suggesting that Pragmatists, Theorists, Reflectors and Activists within each group had similar attitudes towards navigating the domain material irrespective of learning styles.

4. Learning styles did not account for a significant difference between learning style and system design so subjects did not find the operation of the system unsatisfactory.

5. Learning styles did not account for a significant difference in the benefits of system advice.

6. Learning styles did not account for a significant difference in the benefits of a concept map tool.
Relation between Learning outcome, Learning style and Guidance

The correlation coefficients found between learning outcome and general user satisfaction were low. Subjects were satisfied using any of the learning conditions, although the guided discovery condition achieved a higher improvement in score reflecting learning outcome. In terms of learning outcome, guided discovery was not detrimental in terms of the satisfaction obtained.

Ideally, all students would sit through each of the experimental conditions. This would provide information about the relative strengths of each condition. This is obviously not feasible (students cannot undo their learning), so we can only use the qualitative feedback from the questionnaire to gain an insight of the relative strengths of the experimental conditions. From the qualitative results, students were equally happy with the experimental conditions.

11.4 Analysis of User Profiles and Interview Responses

Additional data was collected to provide information about specific issues. These are: (1) user profiles and (2) replies from the semi-structured interview.

11.4.1 User Profile

User profile data was collected from questions at the beginning of the user satisfaction questionnaire to provide a more comprehensive profile of the typical user predicted to use an online system for distance learning.

- Computer usage per week. The subjects spent an average of 12.1 hours per week (Total=1019 hours) using the computer. This showed that for the majority of students it was an essential part of carrying out their undergraduate studies. This was carried out on university facilities and for completing coursework. Some
students reported as high as 50-60 hours.

- Browsing the Internet. "Surfing the web" was an average of 3.7 hours per week (Total=317 hours). Therefore although a minority of 30% (N=25) did spend over 3 hours doing this a week the majority did not (N=59). Therefore computer usage remains predominantly non-Internet related.

- Locating Information for Coursework. This was only carried out by a minority of 23% (N=19) suggesting that many did not use the Internet to do this task (N=65).

- Using the Internet for Learning. In comparison to the total hours spent browsing the Internet (N=317 hours) this was a low amount (N=103 hours). At least two thirds of the time spent online was not specifically for taking a course or for directly using the Internet for learning purposes.

- Type of browser. 70% (N=59) of the sample used Netscape Navigator with the remaining 30% using Internet Explorer (N=25). This suggested that the selection of Netscape Navigator to display the web material was reasonable as the subjects were used to its operation, although Internet Explorer could just as easily be used retaining the same functionality.

- Type of computer. 92% (N=77) of the sample used PC with 8% using Macintosh (N=7). This suggested that the majority of students would access the Internet using a PC.

The data shows that the subjects in this experiment were computer-literate, knew how to navigate with the web browser, and were familiar with different uses of the Internet. It is predicted that this user profile will undergo change with the predicted growth of the Virtual University (see chapter 6) followed by more students using the Internet for learning rather than just browsing (Debreceny, Ellis and Chua, 1995).
11.4.2 Interview Data

An interview was administered as the last part of the experiment to collect qualitative data about different aspects of the experimental conditions. These were used to supplement results from the user satisfaction survey.

- System advice versus Concept maps. When asked whether they would keep the advice aspect of the system or the map, the majority of subjects in the guided discovery system (N=26) answered that they would keep the advice. Reasons given for not using the map in both the guided discovery and map only condition were that: (1) the maps were too small, (2) scrolling made it difficult to read, (3) the material was clear and concise so there was no need for the map, and (4) the contents page was sufficient for helping navigation (as illustrated in Appendix D1). Those who did report usage of the map said that they did so sparingly and mostly at the beginning to help understand the material rather than as a “roadmap”.

- The value of the online test. When examining the replies from all the experimental conditions all the subjects replied that they liked using this function. Reasons given were: (1) it encouraged the learner to work through the material rather than just browsing, (2) the questions helped to focus on the concepts and principles, (3) this aided memorisation as the learner had to apply what was learnt, and (4) the feedback afterwards made learners return to material that they had previously struggled with.

- Speed of the system. Of the sample of 84 subjects, only 2 reported the speed of the system as slow. The others replied that it was either good or adequate. This suggests that the guided discovery condition was not perceived as slower than the other conditions. An often-heard reply was that they were used to waiting a lot longer, highlighting the problem of time delay on web usage generally. The possible effects on learning are discussed in chapter 6.
11.5 Overall Strands of the Analysis

These conclusions demonstrate that learning can be improved by using a guided discovery framework for constructing a WWW hypertext environment. The effect of providing individualistic guidance (using specific components of structured discovery steps with varying levels of questioning, and navigational guidance) was to increase the learning outcome scores to a higher level ($52.19 \pm 3.3$) than the map-only condition ($37.34 \pm 2.41$) and unguided condition ($33.89 \pm 2.78$). Although having a concept map facility did seem to increase the mean score of the learning outcome and could therefore said to have some effect on learning, this was not at a significant level.

This outcome could be explained by the provision of guided advice to support the learner in bridging any conceptual leaps in the understanding of the material, and has reduced the navigation and disorientation problem of navigating in the hypertext information space. This guided approach allows the learner to focus on learning the attributes of the concepts, rather than devoting cognitive resources to keep track of nodes previously visited, their current position and where next to go in the information space. The use of different levels of guidance ensures that the learner is given the correct level of information at the correct time related to the sequence of the discovery steps.

The use of a guided component to structure the discovery process provides a shift previously depicted in Chapter 2, figure 2. The suggestion is that the learner continues to have control over the exploratory process. The learner can select which part of the material to work through next; but with system intervention controlling certain parts of the information space, when it is required that the learner works through particular sequences of material. The questioning, clues and statements, which are part of the guidance process, force the learner to become cognitively engaged with the material at a higher degree. The guidance cues make the relationships between the concepts more explicit so that the learner can embed the expert's understanding of the domain material into a personal cognitive schema of understanding (although this
psychological principle remains tentative and requires further investigation).

The strength of hypertext is in the ability of the user to browse the information space but hypertext for learning is filled with many unresolved issues. The application of hypertext to the WWW for distance learning brings further complications. Related to distance learning are such issues as assessment, teaching support, material design, social/peer isolation and specific adult learner difficulties. In terms of the WWW there are new issues such as those related to distance learning; but with the addition of user modelling, adaptive instruction, web page design, temporal latency, open-corpus of educational material, vast information repositories and haphazard interactivity using continually changing web technologies. Therefore there remains a distinct paucity of principles for designing a WWW-based environment for supporting learning. Some of these problems such as user modelling and adaptive instruction remain problematic for CAI generally rather than just the WWW and learning.

This research has demonstrated that constraining the information space by using system-led guidance can lead to gains in learning without necessarily sacrificing gains in satisfaction. Shaping learning by using guidance cues (such as navigational buttons, system advice messaging) does not prevent discovery taking place. Instead it may prevent the learner from following disordered tangents in the path through the material, reducing non-optimal navigational behaviour and the resolution of misconceptions.

The efficacy of concept maps for structuring learning has been proven to be beneficial for learning in the classroom. The usage of concept maps for alleviating disorientation and in structuring knowledge has also been suggested for hypertext. These problems will be addressed in chapter 12 on Future Research.

The use of AI techniques in the construction of the guided discovery condition was restricted. It was found that the use of the overlay model to capture learner behaviour was sufficient to provide enough information in order to base decisions for adaptive guidance. The use of an approach similar to a rule-based production system provided sufficient inferencing capability, to support limited individualised instruction by the
system. Therefore this system has demonstrated that there may not always be a need to build a powerful AI-based tutoring system in order to support learning.
Chapter Twelve

Conclusion

12.1 Implications of the Research

This research has demonstrated a particular pedagogical approach to designing a hypertext system for learning on the Internet. It has been demonstrated that using guidance, implemented according to a particular methodology, will result in increases in learning outcome and comparable levels of user satisfaction. Electronic Logic is a suitable domain for assessing such a system because it provides both conceptual and procedural material which is non-ambiguous and measurable.

The pedagogical aspect of using the Internet remains a neglected, but invaluable, area of research. The spectrum of teaching styles provide a framework for analysing the components that are characteristic of different methods for teaching. Using this analysis the system designer can translate these approaches to a computerised learning environment. The guided discovery approach has been transferred to a hypertext-based WWW learning environment because it was seen as being able to provide the structure and individualised instruction which was identified as being needed in order to support exploratory student-led learning.

This project was also an attempt to establish the importance of taking a structured approach to the design of systems for learning. There are many issues to be addressed when designing hyperdocuments for learning. Some of these issues are the deconstruction of learning material into concepts and principles, the development of an interconnected model of nodes and links to reflect this, and the selection of an
instructional strategy that can best support the teaching of conceptual material (the instructional design strategy).

This is in combination with tackling technical issues such as user interface design, user modelling and inferencing mechanisms. Associated with this are WWW-specific issues. Both technical (such as network delay, constructing systems able to utilise the Internet browser, tracking and identifying the learner with primarily stateless internet protocols); and issues related to the construction of a ‘virtual university’ (such as no human tutorial support, the problems of designing for online assessment, and learner hesitancy in using new novel methods for learning). The construction of a WWW system for providing guidance during learning is therefore a non-trivial, complex task.

The issue therefore becomes a consideration of whether the increase in learning gains is worth the effort spent in developing the guidance needed to engineer a guided discovery learning environment. This question of effort could be regarded as whether the preparation needed to design the discovery steps, the formulation of the system advice and the online testing (amongst other factors such as possibly learning Java) would result in a large enough increase in learning outcome.

It is suggested in this thesis that the resources needed to build the system merits the time taken to engineer such a learning environment. Providing guidance should be an essential consideration when designing a hypertext-based system for promoting learning, if the aim of the learning is to make it meaningful (as opposed to rote learning of factual data for memorisation). The creation of specific sequential discovery steps to explore the material will allow the learner to gradually converge towards the understanding of specific concepts and principles related to these concepts. Further conceptual support through the use of questioning and advice within the sequences themselves (micro-level support) and within the navigation in the information space (macro-level support) allow the learner to focus on the material rather than on navigational issues.

The design of the experiment to collect data will contribute to the current need for established qualitative and quantitative research in the field of WWW and learning.
environments. The evidence from this research suggests that guidance, although continually discussed in the hypertext literature, has not been implemented using the approaches to the design of the material, the implementation of the educational pedagogy or the integration of these factors into a WWW learning environment, as has been carried out in this project.

The efficacy of this approach in addressing the problems of disorientation, cognitive overhead, navigation, conceptual learning and individualised instruction has been placed in the framework of a guided approach to teaching. The crux of this thesis is in the argument for an overt, well-structured pedagogical approach for a computerised environment for learning, and the specific methods that can be used to carry out this guidance. Further research is needed to compare the effect of different pedagogies for teaching on the Internet, as the guided discovery approach is one of many in the spectrum of possible teaching styles. This approach, with consideration of issues of hypertext, educational psychology and WWW-specific issues; based on adaptation of the learning environment to support the needs of the learner, can be used in the development of future WWW learning systems which continue to use the forte of exploratory, learner-led behaviour.

12.2 Future Work

The research carried out in this thesis has created an architecture for a learning environment based on guided discovery. The subject domain has specifically been on Electronic logic. Hence a possible area of future work is to apply the structure to other topic domains. Electronic logic was specifically chosen due to its lack of ambiguity. Opinions over principles and details are non-contentious and are well established. Therefore further testing could take place of similar topics to determine if the effort required in building such systems would result in a high enough level of learning gain. Another possibility is the selection of more contentious domain topics that rely on the opinions of the learner, with no right or wrong answers to determine how the guided discovery paradigm would perform.
It was also proposed in this project that the provision of concept maps would make a difference in learning outcome and user satisfaction, but this has not been borne out by the results. The suggestion is that the frame used to display the material was difficult to use, requiring the user to continually scroll to view the whole map. This compromise had to be reached because an overly large concept map frame would be at the expense of a much reduced frame for reading domain material or system advice. A possible solution is to provide a pop-up window to display the concept map. The difficulty would then be that the learner would lose sight of the information in the other frames, therefore possibility losing supportive information. Also this would have been another system operation which the subject would have had to remember, hence increasing cognitive overhead. This, however, may be overcome with a more extensive acclimatisation period for operating the system.

Another future area is the infusion of a guided hypertext environment with other WWW technologies that are purported to support distance learning. The system could be incorporated with video-conferencing, online display of overheads by a remote human lecturer, a ‘whiteboard’ for the sharing of notes and diagrams, and other forms of online assessment. For example the creation of online discussion groups or ‘chat rooms’ could make possible the idea of sharing between remote users and is an area for future research. It could be suggested that the essential components are already built by this project, for tailoring parts of the infrastructure to support group collaborative working. More tools could be built that allow different ways to navigate and view the material to be learnt specific to collaborative learning interaction requirements. This is currently being investigated by the LUTCHI Research Group at Loughborough University, U.K. (Edmonds and Quantrill, 1998), and is a fruitful area for potentialising the provision of support for learning with students with differing learning styles and needs.
12.3 Summary

This thesis has outlined the research issues of designing hypertext for learning on the World-Wide Web. The results have demonstrated that learners do not feel hindered when navigating using the guided discovery approach, and that it appears to offer them similar levels of freedom to explore which users experience with conventional, unguided hypertext. Nor do learners feel that the advice is unwarranted, and remain generally satisfied with all the areas of the guided discovery system. It seems justified to argue that if learners are satisfied with using the guided discovery system, the effort required to design and construct a learning environment based on this educational pedagogy is worthwhile for the significant gain in learning outcome that it achieves.

An examination of pedagogical approaches to learning has been discussed with the proposition that a guided discovery approach is needed for the design of the learning environment. A framework for carrying out this teaching style has been proposed, and extensively modified to reflect the particular requirements of both hypertext and WWW-based distance learning issues. A methodology has been put forward to assess the effects of a guided discovery, concept map and unguided condition on learning styles, learning outcome and user satisfaction. Results have shown that providing guidance, structured in a specific manner, can reduce disorientation and cognitive overhead whilst also creating significant gains in learning outcome without having to sacrifice learner satisfaction. It is this pedagogical approach to shaping all the levels of a hypertext learning system, specifically designed for the WWW that provides a novel contribution to supporting distance learning on the Internet.
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Portland, OR.


APPENDICES

Appendix A1: Learning Style Material

The appendix contains the following material:

- Appendix A1.1 - The Learning Style Questionnaire - used to assess preferred learning styles of the subjects.
- Appendix A1.2 - Scoring Scheme for Learning Styles Questionnaire

Appendix A1.1 - THE LEARNING STYLES QUESTIONNAIRE

Name __________________________
Age ______ Male / Female
Name of Course ________________________________
Year of Study _____ Current Years in Higher Education (University level) _____

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed learning 'habits' that help you benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pinpoint your learning experiences that suit your style.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depend on how honest you can be. There are no right or wrong answers. If you agree more than disagree with a statement put a tick by it ( ☑ ). If you disagree more than you agree put a cross by it ( ❌ ). Be sure to mark each item with either a tick or cross.

☐ 1. I have strong beliefs about what is right or wrong, good and bad.
☐ 2. I often carry out actions without caution.
4. I believe that formal procedures and policies cramp people's style.
5. I have a reputation for having a no-nonsense, 'come straight to the point' style.
6. I often find that actions based on guesses are as sound as those based on careful thought and analysis.
7. I like to do the sort of work where I have time to probe all the information.
8. I regularly question people about their basic assumptions.
9. What matters most is whether something works in practice.
10. I actively seek out new experiences.
11. When I hear about a new idea or approach I immediately start working out how to apply it in practice.
12. I am keen on self-discipline such as watching my diet, taking regular exercise, sticking to a fixed routine.
13. I take pride in doing a thorough job.
14. I get on best with logical, analytical people and less well with spontaneous, 'irrational' people.
15. I take care over the interpretation of data available to me and avoid jumping to conclusions.
16. I like to reach a decision carefully after weighing up many alternatives.
17. I'm attracted more to novel, unusual ideas than to practical ones.
18. I don't like 'loose-ends' and prefer to fit things into a coherent pattern.
19. I accept and stick to laid down procedures and policies so long as I regard them as an efficient way of getting the job done.
20. I like to relate my actions to a general principle.
21. In discussions I like to get straight to the point.
22. I tend to have distant, rather formal relationships with people at work.
23. I thrive on the challenge of tackling something new and different.
25. I pay meticulous attention to detail before coming to a conclusion.
26. I find it difficult to come up with wild, impulsive ideas.
27. I don't believe in wasting time by going around the subject.
28. I am careful not to jump to conclusions too quickly.
29. I prefer to have as many sources of information as possible - the more data to consider, the better.
30. Flippant people who don't take things seriously enough usually irritate me.
31. I listen to other people's point of view before putting my own forward.
32. I tend to be open about how I'm feeling.
33. In discussions I enjoy watching the manoeuvrings of the other participants.
34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance.
35. I tend to be attracted to techniques such as network analysis, flow charts, branching programmes, contingency planning, etc.
36. It worries me if I have to rush out a piece of work to meet a tight deadline.
37. I tend to judge people's ideas on their practical merits.
38. Quiet thoughtful people tend to make me feel uneasy.
39. I often get irritated by people who want to rush into things.
40. It is more important to enjoy the present moment than to think about the past or future.
41. I think that decisions based on a thorough analysis of all the information are
sounder than those based on intuition.

☐ 42. I tend to be a perfectionist.

☐ 43. In discussions I usually pitch in with lots of speculative ideas.

☐ 44. In meetings I put forward practical realistic ideas.

☐ 45. More often than not, rules are there to be broken.

☐ 46. I prefer to stand back from a situation and consider all the perspectives.

☐ 47. I can often see inconsistencies and weaknesses in other people's arguments.

☐ 48. On balance I talk more than I listen.

☐ 49. I can often see better, more practical ways to get things done.

☐ 50. I think written reports should be short and to the point.

☐ 51. I believe rational, logical thinking should win the day.

☐ 52. I tend to discuss specific things with people rather than engaging in 'chit chat'.

☐ 53. I like people who are practical in their approach.

☐ 54. In discussions I get impatient with irrelevancies.

☐ 55. If I have a report to write I tend to produce lots of drafts before settling on the final version.

☐ 56. I am keen to try things out to see if they work in practice.

☐ 57. I am keen to reach answers via a logical approach.

☐ 58. I enjoy being the one that talks a lot.

☐ 59. In discussions I often find I am the realist, keeping people to the point and avoiding speculation.

☐ 60. I like to ponder many alternatives before making up my mind.

☐ 61. In discussions with people I often find I am the most dispassionate and objective.

☐ 62. In discussions I'm more likely to adopt a 'low profile', rather than to take the lead and do most of the talking.

☐ 63. I like to be able to relate current actions to a longer term bigger picture.

☐ 64. When things go wrong I am happy to shrug it off and 'put it down to experience'.

☐ 65. I tend to reject wild, spontaneous ideas as being impractical.

☐ 66. It's best to consider actions before carrying them out.

☐ 67. On balance I do the listening rather than the talking.

☐ 68. I tend to be tough on people who find it difficult to adopt a logical approach.

☐ 69. Most times I believe the end justifies the means.

☐ 70. I don't mind hurting people's feelings so long as the job gets done.

☐ 71. I find the formality of having specific objectives and plans stifling.

☐ 72. I usually the 'life and soul' of the party.

☐ 73. I do whatever is convenient to get the job done.

☐ 74. I quickly get bored with methodical, detailed work.

☐ 75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events.

☐ 76. I am always interested to find out what other people think.

☐ 77. I like meetings to be run on methodical lines, sticking to laid down agenda.

☐ 78. I steer clear of subjective or ambiguous topics.

☐ 79. I enjoy the drama and excitement of a crisis situation.

☐ 80. People often find me insensitive to their feelings.

Any other comments?
Thank you for your help in answering this questionnaire

Appendix A2 - Scoring Scheme for Learning Styles Questionnaire

<table>
<thead>
<tr>
<th>Activist</th>
<th>Reflector</th>
<th>Theorist</th>
<th>Pragmatist</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7</td>
<td>1</td>
<td>5</td>
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<tr>
<td>4</td>
<td>13</td>
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<td>76</td>
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<td>80</td>
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Appendix B1: Post Exam

The appendix contains the exam taken after using the experimental condition.

Exam

Name

Learner ID e.g B

Date

This is a short exam consisting of 18 questions.

Some of the questions are multiple-choice, whereby you tick the relevant box; other questions involve you filling in the columns with numbers. If you make a mistake in your answer, cross out the incorrect answer and put the new correction next to it.

YOU ARE NOT ALLOWED TO USE ANY NOTES THAT YOU MAY HAVE MADE DURING THE INTERNET SESSION. SOME OF THE QUESTIONS MAY BE RELATED TO LESSONS THAT YOU MAY NOT HAVE YET ENCOUNTERED. TRY AND DO AS MANY AS YOU CAN.

(1) How do you denote, in binary, a signal being:

- On / true? ______ Answer
- Off / false? ______ Answer

(2) What do the following diagrams denote?

\[ (A.B) \]

Answer

\[ A \]

\[ B \]

Answer
(3) Fill in the blank answer in the following definition if high voltage represents 1, or 'true' and low voltage represents 0, or 'false':

The _______ gate has a high voltage output only if both Input A and Input B are at a high voltage.

The _______ gate has a high voltage output only if the Input is low voltage.

The _______ gate has a high voltage output only if Input A OR B is at a high voltage but not when both are at a high voltage.

(4) What logic device does the following truth table signify if P represents the output?

<table>
<thead>
<tr>
<th>A</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

(5) What does this Boolean notation \((A+B)'\) represent?

Is it a:

- NOR gate  
- XOR gate  
- NAND gate

Does it mean?

- A AND B is negated  
- A OR B is negated
• A NOT B is negated

(6) In a logic circuit, what would A, B and C represent if D is the output?

- A is an input, B and C are outputs
- A, B and C are all inputs
- A, B and C are all outputs
- A and B are inputs and C and D are outputs

(7) If B is 1 what is B' ? Answer

(8) If X is 0 and Y is 1, what is the answer for:

- X OR Y ? Answer
- X AND Y ? Answer

If X is 1 and Y is 1, what is the answer for?

- X OR Y ? Answer
- X AND Y ? Answer

If X is 0 and Y is 1, what is the answer for?

- X XOR Y ? Answer
- X NAND Y ? Answer

If X is 1 and Y is 1, what is the answer for?

- X XOR Y ? Answer
- X NAND Y ? Answer

(9) What logically is another name for a not AND gate? Answer
What logically is another name for a not OR gate? Answer

(10) Which Boolean expressions describe the output of the following two truth tables?

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>P</th>
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</tbody>
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B1 c
(11) Complete the following table:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A'</th>
<th>B'</th>
<th>A • B</th>
<th>(A • B)'</th>
<th>A + B</th>
<th>(A +B)'</th>
<th>A' • B'</th>
<th>(A' • B')'</th>
<th>A' + B'</th>
<th>(A' +B')'</th>
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(12) For the following table A, B, C and D represent the input columns; P is the output column.

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<th>Column 4</th>
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</table>

Write out the minterm for this table?

Answer
Write out the sum-of-minterms for this table? Include the full notation, such as all inverted parts.

(13) Four security men share the task of walking around the university campus. As each leaves to carry out this task he inserts his individual security ID card (A, B, C or D) into a machine and removes it from the machine when he returns. A green light shows (P) provided two, and only two, watchmen are on patrol. Complete the truth table below and write the Boolean expression (sum-of-minterms) for P.

<p>| | | | | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>P</td>
<td>Minterms</td>
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<td>0</td>
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</tbody>
</table>

(14) An insurance company classifies requests for motor insurance according to whether (A) the applicant is less than 25 years old; (B) the age of the vehicle is less than 5 years old; (C) the engine capacity is less than 2 litres; and (D) previous insurance claims have been made. The maximum premium is charged (P) for

(i) applicants under 25 with vehicles more than 5 years old;
(ii) applicants under 25 with vehicles less than 5 years old who have made previous claims;
(iii) all applicants with vehicles less than 5 years old and capacity more than 2 litres with previous claims; or
(iv) all applicants 27 years or over with vehicles less than 5 years old and capacity less than 2 litres with previous claims.

Complete the truth table and write the Boolean expression (sum-of-minterms) for P.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>P</th>
<th>Minterms</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

(15) In binary addition, what is the following answer?

```
1
1
1
```

Answer

```
1 1 1
1 1 1
```

Answer

```
1 0 1
1 0 0
```

Answer
(16) Fill in the following Half-adder truth table, if C is carry and S is the sum of the output:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
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<tr>
<td>1</td>
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<td></td>
</tr>
</tbody>
</table>

(17) Fill in the answers for the following truth table:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A OR B</th>
<th>A XOR C</th>
<th>NOT (A XOR C)</th>
<th>(A OR B) AND (NOT (A XOR C))</th>
<th>NOT ((A OR B) AND (NOT (A XOR C)))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

(18) Given the following expression what is the answer, if X is 0, Y is 1 and Z is 1.
Show your working out:

\[
\text{NOT } ((\text{X OR Y}) \text{ AND } (\text{NOT (X XOR Z)}))
\]

Answer

End of Test
Appendix C1: User Satisfaction Questionnaire (Guided Discovery)

System Questionnaire

Name: ____________________________________________

This is not a test. There are no correct or incorrect answers. This is to ask you about your impressions of the system.

1. How many hours do you spend using a computer per week? ______ hours
2. How many hours do you surf the Internet per week? ______ hours
3. Do you use the Internet just for finding material to put into coursework? yes no
4. Do you use the Internet for learning? ______ hours
5. Which Internet browser do you use?
   - Netscape browser
   - Internet Explorer
   - Other
   - Don’t know

6. Which computer do you usually use:
   - PC
   - Macintosh
   - Sun workstation
   - Other
   - Don’t know

Please circle one of the numbers in response to each of the questions.

<table>
<thead>
<tr>
<th>STRONGLY DISAGREE</th>
<th>DISAGREE</th>
<th>UNDECIDED</th>
<th>AGREE</th>
<th>STRONGLY AGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. I enjoyed using the system.
2. The system was easy to use.
3. The system was flexible to use.
4. I have learnt more using this system than reading it from a book.
5. I would have preferred reading this material from a book. It would have made it easier to understand.
6. I did not know which part of the material to select next to read.
7. I became confused with the organisation of the material.
8. I became confused by the way the links were set up.
9. I understood the connections in the material.
10. I was confused about which material I had visited because the links stayed the same colour.
11. I often got ‘lost’ when working through the material.
12. I felt that I had enough freedom to explore.
13. If I had learned this material from a textbook, it would have been easier.
14. If I had learned this material from a lecture, it would have been easier.

15. I did not like learning material this way.

16. It is difficult to read such a large amount of material from the screen.

17. The screen was too cluttered.

18. I would have preferred more freedom to explore the material.

19. The advice helped me to understand the material.

20. The advice was given at the correct moment.

21. I received advice when I felt it wasn't needed.

22. The advice given was easy to follow.

23. Whether the advice was there or not made no difference.

24. It was useful to receive the advice in the form of questions being asked.

25. The ‘Further explanation’ sections helped me to understand other concepts.

26. The ‘Further explanation’ sections helped me to recognise why I had made some mistakes.

27. I needed more structure and direction than the system had provided me.

28. The feedback received after each test session made me work through material which I probably would not have.

29. I wanted to receive more feedback about my progress.

30. I wish I could choose when to receive advice rather than the system deciding for me.

31. The Concept maps were useful when read with the advice.

32. The Concept maps were useful in helping me to remember the material.

33. The Concept maps helped me to understand the material.

34. The Concept maps helped me to ‘navigate’ through the material.

35. The Concept maps helped me to understand how some concepts were related to others.

36. The Concept maps were easy to read.

37. The navigation buttons sometimes took me to pages that I had not expected.

38. The words which appeared at the bottom of the screen helped me to understand the way the links were set up.
This is the first screen that the user views, selecting from the Contents page. Initial advice is given by the system to structure the first steps of the exploratory process.

The example given here and in the remaining screenshots is of a user working through lesson 6.
Appendix D2: The Operation of Level One Guidance

User selects links in the material, with system advice and concept maps present.

6. Problems With More Than Two Inputs

Some three-input functions simply extend the definitions of AND, OR and their inverses.

For example, the AND of three inputs is written

\[ P = A \land B \land C \]

The NOR of three inputs is written

\[ (A \lor B \lor C)' \]

The following truth table should be recognizable as the AND function for a three-input description of the earlier example of the conditions needed for an engine to drive the wheels.

It has a single 1 at the bottom of the output column (P):

\[ \begin{array}{ccc|c} 
 A & B & C & P \\
 0 & 0 & 0 & 0 \\
 0 & 0 & 1 & 0 \\
 0 & 1 & 0 & 0 \\
 0 & 1 & 1 & 0 \\
 1 & 0 & 0 & 0 \\
 1 & 0 & 1 & 0 \\
 1 & 1 & 0 & 0 \\
 1 & 1 & 1 & 1 \\
 \end{array} \]
Appendix D3: Online Test for Lesson Six

Question 3:

The following truth table gives the minterm \( P = Q + R + S + T \). What is the sum-of-minterm for this?

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>P</th>
<th>Q</th>
<th>R</th>
<th>S</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

1) \( P = A' \cdot B' \cdot C' \cdot D + A' \cdot B' \cdot C \cdot D' + A' \cdot B \cdot C' \cdot D + A \cdot B' \cdot C' \cdot D' \)
   – this answer

2) \( P = A \cdot B \cdot C + A' \cdot B' \cdot C' \cdot D' + A' \cdot B \cdot C \cdot D + A \cdot B \cdot C' \cdot D' \)
   – this answer

3) \( P = A' \cdot B' \cdot C' \cdot D + A' \cdot B' \cdot C \cdot D' + A \cdot B \cdot C' + D + A \cdot B \cdot C \cdot D' \)

Please select an answer only ONCE and WAIT for the page to be retrieved!

Online Test – multiple choice selection
Appendix D4: System Feedback for Failed Online Test

The advice window highlights which answers are wrong and possible explanations why this has occurred. The materials window displays the correct answers.
Appendix D5: New links opened due to Failure on Online Test

Advice Window informing the value of following new links

Lesson 6
Problems With More Than Two Inputs

6.1 Problems With More Than Two Inputs

6.1.1 The Operation of a Truth Table with three inputs

6.2 Applying OR to Problems with 3 Inputs

6.2.1 Further Explanation of how to derive the Minterm

6.2.1.2 Step-by-Step Explanation of the Process

6.3 Summary of Learning Objectives in this Section

Concept Map

Level 2 Guidance steps

Level 3 Guidance steps
Appendix D6: Level Two Guidance

User has selected to carry out further discovery steps to clarify any misconceptions, hence the display of level two guided advice. Note navigation bar is turned off to force the user to follow the sequence fully.

Level Two Guided Advice

8.2.1 Further Explanation of Carrying out the Evaluation Process

Determine the amount of columns you would need for this truth table.

How many different variables and logical operators are there?

Concept Map specific to material

The Boolean expression is:

\[ \text{NOT}(x \lor y) \land \text{NOT}(x \lor z) \]

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>z</th>
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<tbody>
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</tbody>
</table>

Domain Material
Appendix D7: Level Three Guidance

The user has chosen further system support for understanding the same concept which was previously explained in level two guidance. The discovery step is reduced to its smallest size.

8.2.1.3 Step-by-Step Evaluation of Logical Compounds

It may help to write

\[
\text{NOT}((0^x \text{ OR } 0^y) \text{ AND } (\text{NOT } (0^x \text{ XOR } 1^2)))
\]

So that it is easier for you to look for the correct row in the truth table with:

- \(x\) representing column \(x\)
- \(y\) representing column \(y\)
- \(\text{NOT } (0^x \text{ XOR } 1^2)\) representing column \(x\)

Now we are left with two expressions: \((0 \text{ OR } 0)\), and \((0 \text{ XOR } 1)\).

\[
\text{NOT}((0 \text{ OR } 0) \text{ AND } (\text{NOT } (0 \text{ XOR } 1)))
\]
Appendix D8: System Intervention for Non-optimal Navigation strategy

User is advised that the selection of a specific link is not desirable at this particular point in the learning.