ADAPTIVE HYPERMEDIA, LEARNING STYLES AND STRATEGIES WITHIN THE EDUCATIONAL PARADIGM

By

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Table of Contents

List of Figures

List of Tables

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ABSTRACT

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ADAPTIVE HYPERMEDIA, LEARNING STYLES AND STRATEGIES WITHIN THE EDUCATIONAL PARADIGM

by Namira Bajraktarević

In the past decade educational researchers have focused considerable efforts on defining and developing adaptive techniques that support students in increasing their knowledge in web based educational systems. In order to describe the adaptive hypermedia approach and its relationship to student learning, a review of hypermedia learning environments has been undertaken.

The consequences of adapting the learning style and learning strategies differences have not been thoroughly pursued by adaptive hypermedia researchers. The undesired effect of 'ordinary' hypermedia learning systems is that they may not effectively target the students' learning styles. Many researchers recognise the importance of personalising hypermedia to meet students' needs and the literature review suggests that students perform better in hypermedia based learning environments that are configured to support their learning needs.

Two novel adaptive systems have been developed, based on the theory of learning styles and learning strategies. This first part of the investigation presents the findings of an evaluation of a hypermedia learning system that incorporated global and sequential learning styles. Details of the design regarding the structure of the information and linking mechanisms are presented. A review of the results obtained by evaluating the use of the system suggests that students, who use hypermedia-learning environments that supported their preferred learning style, performed significantly better.

Building on this learning styles research, the study presents the concept and design involved in building an adaptive hypermedia system that supports application and use of "higher order" learning strategies, such as summarising and questioning. The system has been named ILASH, standing for Incorporating Learning Strategies in Hypermedia. The thesis presents the findings of the evaluation of the system.

Students were expected to achieve significant improvement in learning outcomes while interacting with the adaptive version of the system compared to the non–adaptive version. The results obtained from the summative evaluation suggest that the adaptive features provided by the system have significantly contributed towards improved learning performance. The development of the system emphasises the fact that adaptive educational systems can match some of the students' learning preferences and may have implications on the design of web based educational courseware.

Chapter 1. Introduction

1.1. Research problem and its significance

The emergence of hypermedia technology has resulted in some attempts by the educational community to teach using hypermedia environments. However, there has been little research to demonstrate how effectively hypermedia courseware can accommodate students with different learning characteristics. Because of the way different students perceive, process or view information, material for a hypermedia system can be organised in such a way that students can gain great benefits from using it.

The process of looking for information becomes time consuming and frustrating to some students, especially when they are just looking for general headlines or an overview, while other students may become confused if only the main headings of the lecture are presented, without going into detailed information.

In addition, little research has explored the combined effect of learning styles and learning strategies in the context of hypermedia resources. This thesis illustrates the differences between traditional educational hypermedia environments, offering students freedom in learning and the next generation of such systems, adaptive educational systems, which have potential to enhance learning and overcome the issues present in 'ordinary' hypermedia systems. For example, even though traditional hypermedia systems are flexible, they do not necessarily take into account the students' learning differences and preferences, such as preferred learning styles. Traditional learning systems do not contain techniques aimed at reducing common problems, such as cognitive overload, decreasing the time students spend learning or finding specific information. The focus in many hypermedia systems is on presenting information in the same way for everyone. Such systems do not provide learning support for the application of effective learning strategies or the personalisation of the learning environment. Adaptive educational systems have the potential to fill this role.

Individual differences in human processing of information are an important factor in hypermedia research in terms of the way the designers of hypermedia software make connections and links between different pieces of information. Adaptive hypermedia systems offer the possibility of individualised instruction by offering personalised navigation and presentation of the courseware, and therefore help in overcoming comprehension and learning issues faced by the students. Adaptive educational systems can accommodate the learning differences between students and match their learning needs.

Based on the theoretical work and the traditional application of learning differences, this thesis considers the design of an adaptive hypermedia system in an educational context, i.e. from the perspective of the learning and cognitive processes engaged by learners. Special emphasis in this research is given to the adaptive techniques and the representation of learning styles and strategies in an adaptive hypermedia environment. Part of this research is to investigate how the students' individual learning styles influence the learning effectiveness in hypermedia. Underlying the study are various aspects of learning styles and strategies employed by individuals. This research proposes a new way to accommodate and adapt some learning styles and strategies when designing hypermedia user interfaces. This thesis demonstrates two methodologies when adapting to student preferences. The work resulted in the development of two adaptive hypermedia applications that apply a combination of adaptive techniques to achieve the representation of individual learning differences.

1.2. Structure of the thesis

To describe the study, the thesis is divided into a number of chapters. Chapter 2 introduces concepts such as learning in adaptive hypermedia environments. It gives an overview of the notion of adaptive hypermedia and its application in educational environment. An overview of a collection of existing educational adaptive hypermedia systems and the adaptive techniques used is documented. The chapter also discusses the research into learning styles theories and adaptive hypermedia, to gain a general idea of which adaptive hypermedia techniques are most widely used in current educational technologies as well as how a variety of learning styles have been incorporated adaptively.

Chapter 3 presents a literature review on learning styles research and identifies the necessity to address learning differences in hypermedia learning systems. Identifying educationally critical aspects required for a student's experience of learning and its application is seen as a prerequisite for addressing the issue of an individualising learning process.

Chapter 4 discusses the design and architecture of the LSAS (**L**earning **S**tyles **A**daptive **S**ystem) system that employs an interpretation of so-called global and sequential learning styles. It also discusses the navigational and linking mechanisms adopted in the system.

Chapter 5 presents the usability study of LSAS and the structured, iterative techniques used for the formative evaluation of interaction with the system. Also, various user interface evaluation techniques were reviewed to give an insight into how hypermedia and adaptive hypermedia software are evaluated within an educational environment. General issues when evaluating educational hypermedia are discussed.

Chapter 6 deals with the methodology and results of the empirical study conducted to evaluate the effects of incorporating learning styles within a hypermedia system. The first section of Chapter 6 reports the results of the pilot evaluation that was conducted. A later section covers general issues involved in evaluating the system and provides the empirical results of the match and mismatch of learning styles.

Chapter 7 provides detailed background for the literature review on cognitive learning strategies and focuses on the two strategies that form the basis of the second adaptive system called ILASH (**I**ncorporating **L**e**A**rning **S**trategies in **H**ypermedia). This chapter explains the terminology used, as well as the application of learning strategies in hypermedia.

Chapter 8 offers detailed coverage of the design, the adaptive systems' architecture, adaptation rules, adaptation techniques used and the user model developed by the author as part of the second phase of the study.

Chapter 9 reports the results of the experiment in greater detail and discusses the statistical significance of the results of the quantitative evaluation conducted on the system. This chapter discusses important findings, such as the benefits expected when introducing adaptive hypermedia into education.

Finally, Chapter 10 presents the summary of the study and the concluding remarks on the problems with evaluating adaptive systems and suggests steps for further research in the field of adaptive educational hypermedia.

1.3. Abbreviations

AES	Adaptive Educational Systems
AH	Adaptive Hypermedia
AHS	Adaptive Hypermedia Systems
ANS	Adaptive Navigational Support
CAI	Computer Aided Instruction
CAL	Computer Assisted Learning
CBI	Computer Based Instruction
ILE	Interactive Learning Environments
ITS	Intelligent Tutoring Systems
WWW	The World Wide Web
Web	The World Wide Web

Chapter 2. Adaptive educational hypermedia

2.1 Introduction

This chapter discusses the papers covering a number of adaptive hypermedia systems, to gain a general idea of what adaptive hypermedia techniques are most widely used in current educational technologies. This chapter summarises current applications, which adopt relevant adaptive hypermedia techniques and concepts.

2.2 Hypertext and hypermedia

The theoretical background and development of hypertext is rooted in cognitive psychology and the assumption about the human thought process. The notion of hypertext and hypermedia first evolved from Vanevar Bush's paper titled '*As we may think*' (Bush, 1945), in which he described an automated library of records indexed associatively, i.e., mimicking the structure of the human brain, whereby people think in a non-linear, associative manner. This theorised machine, dubbed "Memex" would be designed to augment human memory and provide its users with instant access to information. Such a machine would serve as a huge repository of human knowledge and be accessible to all. Memex was a precursor to hypertext, a term first described by Nelson (1965) almost 20 years later, where units of information or nodes are connected by links and such documents can be explored in whatever order desired. One of the hallmarks of hypertext is its non-linear structure and Nelson preferred to call it "Linktext", "Jumptext" or "Zapwrite". On the other hand, the term hypermedia was described as something that...."simply extends the notion of the text in hypertext by including visual information, sound animation and other forms of data" (Nelson, 1987).

Hypermedia, in the context of this study refers to an application that combines the non-linear structure of hypertext and the inclusion of additional media elements (text, graphics, sound, video) to enhance the learning experience.

The notion of hypertext, or information chunks connected by links, has been present for quite a while. This is evident in the emergence of the Internet as one of the key technological developments of the 20^{th} century. It arrived on the scene in the early 1960s as a means for the US military to connect their nationwide array of computers. In its early days, the Internet was difficult to navigate, mainly due to the immense amount of information disseminated. However, in 1989 Tim Berners-Lee, who was working at the European Particle Physics Laboratory, came up with a way to identify and navigate between documents strewn across global networks using a simple system of 'hyperlinks'. A year later, he wrote a program that effortlessly jumped between online documents regardless of their physical location. Since then he has been credited as the man who invented the Web. The Web, as a hypermedia system, uses documents, nodes, and pages interrelated by a set of links.

2.3. Hypermedia and constructive learning

The potential of using the Web for learning was realised very soon after it was created. One of the main benefits of the Web is that it is an easy-to-use delivery medium. Hypermedia based learning can be described as an environment where learners can traverse the courseware according to their own pace, and sequence, i.e., gain more control over the interaction with the content (Laurillard, 1993). Individual differences in the abilities and preferences of students have an influence on their responses to information presented in alternative ways. Various learning preferences can be accommodated in such an environment. The challenge is to develop a system that is both comprehensive and will satisfy the demand of different learning styles from an educational point of view. Ebersole (1997) states that in addition to the collection and organisation of useful content, the multimedia author must create a user interface that facilitates access to content. This user interface should be created with careful attention to the mental processes that the user is likely to employ. Recker *et al.* (1995) argue that hypermedia systems and the structure of the system should be based on the cognitive aspects of the user. One direction of hypermedia research focuses on how students perform in a hypermedia environment, especially on an educational web site. The designer of the hypermedia material usually imposes a knowledge structure of a specific topic upon the learner. In most user interface designs, a requirement is to have the interface intuitive to most people. Structuring of information to suit different learning styles needs careful consideration in the design of hypermedia courseware. Hypermedia courseware allows the delivery of learning materials, which can accommodate different learning needs, by customising and structuring access to the vast array of information available. What information is presented and how it is organised and structured is an important factor to take into account when designing the user interface.

As students browse the Web as learning environment, they perform the reading process. Reading has been defined by Hoefer (2002), as "an active, constructive, meaning-making process". The effectiveness of a system using hypermedia depends on the quality of the underlying material and the pedagogical framework used. One of the modes of study with hypertext would appear to be *browsing*. Whalley (1993) asserts, "when the student is required to develop a deeper understanding, then browsing is likely to be inappropriate". When they browse, the learning effect is secondary, as the purpose of the browsing is not learning. According to Jonassen (1993), simply browsing hypertext is not engaging enough to result in more meaningful learning. Hammond (1993) points out that,

> *"a cursory browsing of materials will result in shallow processing, few elaborations and poor retention".*

However, the amount of knowledge gathered during browsing cannot be disregarded. The way to support learning from browsing is an important issue in learning systems (Nomoto *et al.*, 1997).

In developing comprehension of material, a student builds a mental representation of the contents of a document. This mental representation involves linking small pieces of information together to form larger chunks in the form of a hierarchical macrostructure (Thüring, Mannemann and Haake, 1995). A reader more readily comprehends text when it is coherent, that is, when it presents the information in a way that facilitates linking between discrete elements and the chunking of linked elements into larger items (Oliver and Herrington, 1995). Taking these points into consideration, researchers began to investigate the functional features of hypermedia and how these features interact with individual learners' characteristics.

Shikano, Recker and Ram (1998) proposed that the access to and structure of the learning system should be based on cognitive aspects of the students, *i.e.,*, they should be cognitively relevant to learning, reasoning and information seeking goals. Foltz (1996) points out: "a model of hypertext comprehension must consider both the information the reader gains from the text and how that information can affect the reader's choice of strategies for proceeding through the text". Jonassen (1988) suggests extending the learner's cognitive approaches to learning through adaptive, intelligent use of computer courseware and learning materials.

2.4. Origins of adaptive hypermedia and adaptive educational systems (AES)

Using the Web as a learning resource has its benefits and disadvantages. The Web enables distribution of educational documents, in which content is presented using a wide variety of media types (hypertext, graphics, animations). The Web seems a natural vehicle for learning facilities, but of limited effectiveness because simple browsing of Web documents does not necessarily lead to successful learning. While the Web offers access to a vast range of learning resources, exploiting these effectively and in a timely manner depends on the learner. There is a need to create such Web based applications that will cater for different users in different ways and at different levels of complexity, by applying a kind of adaptation according to the individual, which may be determined via the manner in which the student interacts with the application. The growing impact of IT on learning leads to changes in the way courses are delivered in secondary schools. By incorporating Web based software that provides individualised learning approaches may help motivate and appeal to learners.

2.5. Historical developments of adaptive hypermedia

Adaptivity in hypermedia systems have a beginning in the early 1950s, when new technologies in the field of artificial intelligence (AI) provided an opportunity for implementing and automating a variety of theoretical computations. The application of AI technologies to learning was seen as a solution to the problem of providing personalised learning experiences. ITS (intelligent tutoring systems), (Beaumont, 1994, Kay & Kumerfield 1994, Brusilovsky *et al.,* 1996, Self, 1999) have been a focus of research in applications of AI to education for the past 20 years. The very early applications of such technology to education were in CAL (computer assisted learning)(Self, 1985), CAI (computer–aided instruction)(Kulik *et al*, 1986) and CBI (Computer Based Instruction).

CAL is an all-encompassing term to describe any educational use of computers. As such it provided a form of education away from static environments such as books. CAL systems presented instructional content in more dynamic ways. In such environments students could navigate the courseware based on their needs by skipping between topics. CAL environments could assist students by adding multimedia elements such as simulations, video and audio features.

CBI systems can assist students in diagnosing their weaknesses and strengths in problem-solving exercises, by providing problem-based feedback. CBI systems are characterised by the use of software that relied heavily on 'learning by doing' through text drill-and-practice simulations. The CBI software was a reflection of the educational practices of the time, which were dominated by behavioural learning principles. The learning was passive, the students did not receive experiential feedback and it was prescriptive in nature.

CAI systems evolved in the 1950s as individual instruction systems. They opened up new possibilities for individualised instruction by teaching diagnostically. Kullick *et al.* (1985) conducted most work on the effectiveness of CAI systems in education in the 1980s. Such systems were not found to be effective in raising achievement levels, the quality of teaching nor the student's satisfaction about a subject, Kullick & Kullick (1991).

One of the issues with the CAI and CAL learning environments is that the content organisation is still static. Although they provide visual aids, as well as a degree of the learner control of learning pace, they do not provide dynamic reorganisation of the content. They do not change or adapt according to a student's navigation, and are very didactic environments.

With the introduction of hypermedia systems, the educational science and practices started moving from the behavioural approach to learning to the cognitive approach, where the software facilitated learner's interaction and information processing. Hypermedia systems presented another step up from CAL systems, as environments that provided ability to distribute CAL without large costs. As exploratory environments, hypermedia systems provided 'learning by experimentation'. Similar to CAL and CAI systems, they offer highly intensive visual environment and also can reduce learning time by imposing a self-paced style of learning. In contrast to CAL, hypermedia systems provide a non-linear exploration. They are much more dynamic and interactive systems. Hypermedia supports constructionist (Papert, 1993) views of learning which hold that learning takes place when students actively and collectively build knowledge structures. *Microworlds* were an example of the new exploratory or 'inquiry based' learning that supported the constructionist point to view. Harel and Papert (1990) created a "total learning environment" in which students simultaneously learned fractions and Logo programming. The students' goal was to design and develop a Logo program to teach something about fractions. The learning environment integrated the experimental children's learning of fractions and Logo, with the design and programming of instructional software. Logo provided powerful computational facilities and a completely different way of talking about education. Hypermedia systems exemplified the 'constructivist' approach to learning (Jonassen, 1991) where learning is regarded as the formation of mental models. In this view of learning, the students build knowledge, based on their previous understanding, by dynamically interacting with the learning material. Having said that, the hypermedia systems were criticised for a lack of expert guidance, a lack of structure of learning materials and for causing the effect of 'being lost' and so called cognitive overload effects.

The beginnings for the provision of individualised feedback are reflected in the development of user models within hypermedia environments. Hypermedia systems were used for the presentation of learning contents. They were historically developed as a means for structuring text based documents by links and integrating different media formats such as audio, video and graphics. The presence of navigational tools helped student orientation and facilitated the decision-making regarding which links to follow next.

In the late 1980s and early 1990s a lot of research was conducted into ITS and their use in individualised instruction. ITS, like CAI systems, have attempted to implement traditional methods of teaching and learning. In these systems students were required to follow content without direct supervision from a tutor. The developers of ITS have shown that they can significantly improve the speed and quality of learning, mainly by providing one-to-one tutoring interaction. However, such systems were limited by the knowledge-model assumptions the expert author embedded into the software.

It is claimed that AHS offer an improvement on the traditional classroom, as well as traditional CAI and ITS systems, as they have the potential to offer personalized attention and individualised instruction. Traditional non-adaptive educational hypermedia systems provide the same access to information to all users and present information in the same way. On the other hand, an adaptive hypermedia system can support acquisition of knowledge processes and can adapt to incorporate individual differences such as level of knowledge and cognitive student characteristics. An AHS can support the students in navigation by suggesting relevant links to follow, providing additional information on those links and limiting navigational options. An AHS can achieve that by obtaining, storing and maintaining information about the students and their actions. A student model is used to adapt the display characteristics of the interface to the needs of the learner. The student is guided through the system by modifying the access, appearance of links and content within the hypermedia application. The process has a possibility of being highly individualised and personalized. AHS are intended to provide a balance between learner control (exploration/inquiry based learning) and system control, so some AHS provide appropriate levels of support but at the same time allow free navigation. Adaptive educational systems provide dynamic reorganisation of content, they are more student-centred and versatile than any other computer based environment.

2.6. Techniques of adaptive hypermedia

To achieve the above-mentioned claims, adaptive systems need to apply adaptive techniques within a hypermedia environment. Brusilovsky initially described adaptive hypermedia systems in 1996, as "methods of providing adaptation in hypermedia systems". The two main techniques distinguished by Brusilovsky (1996) are adaptive presentation and adaptive navigation support. These adaptive techniques can be characterised by knowledge representation with a specific adaptation algorithm.

2.6.1. Adaptive presentation techniques

Adaptive presentation techniques are described as the ones used for modifying the content and presentation of information, according to the needs of users. They determine how the information is delivered. They present different media and modify content (text or other content) depending on a user's preferences. Adaptive content presentation can be achieved through inserting or removing chunks of information or 'conditional fragments' (*AHA,* DeBra and Calvi, 1998). Other adaptive presentation methods include shading or dimming of fragments (*Sady*, Hothi and Hall, 1998), sorting fragments in some order, or using stretchtext (*MetaDoc*, Boyle 1994).

2.6.2. Adaptive navigational support techniques

Adaptive navigational support techniques are described as techniques used to alter the appearance and behaviour of links in hypermedia. Techniques such as link annotation (ELM-ART, Brusilovsky *et al.*, 1996), link sorting (*Hyperflex*, Kaplan, *et al.,* 1998), link hiding and direct guidance (ISIS- Tutor, Brusilovsky and Pesin, 1994), are all adaptive navigation techniques. Direct guidance implies a recommendation of the next 'best' link for a user to visit; link sorting displays links in an order ranging from best to worst for a particular task; link hiding refers to hiding 'inappropriate' links; link annotation refers to modifying the appearance of links, usually using colours; link generation implies creating links where there used to be normal text, and map adaptation is about changing an overview in graphical form of the link structure.

A taxonomy of adaptive hypermedia technologies that have evolved over the past few years is shown in Figure 2.1.

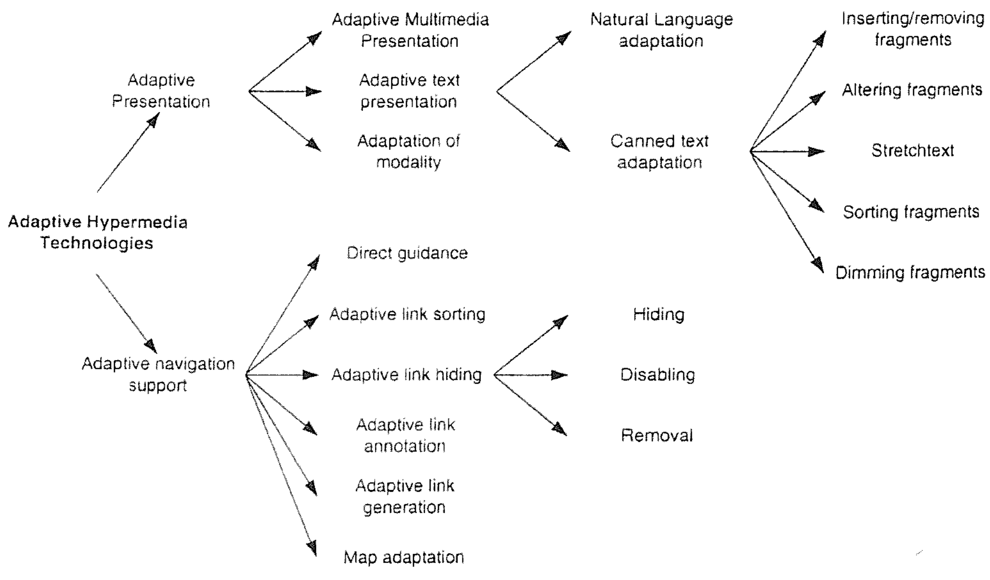

Figure 2.1. The updated taxonomy of Adaptive hypermedia technologies (Brusilovsky, 2001)

Major components of adaptive hypermedia have been identified as the DM (domain model), the UM (user model) and the AM (adaptation model) - Wu et al. (2000).

1) Domain Model

The Domain model consists of a set of domain concepts. It describes how the content is structured, and the knowledge prerequisites. It consists of concepts and concept relationships that are usually determined by the author of the hypermedia courseware.

2) User model (UM)

For an AHS to be tailored to the student, the UM is the essential component of individualised learning. It represents the system's information about aspects of the learner's characteristics such as their knowledge state, learning preferences, experience level (such as novice or expert) and interests. The UM is essentially used to personalize the interaction and present the courseware in a way that the student can relate to. The model is usually acquired using a variety of questionnaires, tests, or tracking browsing activity and/or navigation behaviour throughout the use of the system.

Building the student model can be a finely grained process and involves finding out about who is to be modelled, and what their knowledge and goals are. All this information is needed in order to provide assistance and feedback to the learner. While these variables change throughout the interaction with the system, the UM needs to dynamically incorporate the changes. In the majority of recent Adaptive Educational Systems (AES), the UM contains some stereotypical knowledge of the learner, such as novice of expert (*Hypertutor*, Pèrez *et. al.* 1995, *Webmath*, Tsiriga and Virvou, 2002).

The system's model of a user can be implicit or explicit. An implicit model is embedded into the design. It contains stereotypical information about a user. Explicit models accurately represent the user as the model is constructed, whilst the system runs. This type of model is usually used in adaptive hypermedia and the model is created by gathering data from the user's interaction, feedback and explicit user settings. Adaptation can be performed using prior knowledge (*Netcoach*, Weber and Weibelzahl, 2002), different knowledge states (*AHA!,* De Bra and Calvi, 1998), a student's cognitive state (Mathé and Chen, 1994), learning style preferences (*CS383*, Carver, 1996, *LSAS*, Bajraktarević *et al.*, 2002) or reading speed (*JointZone*, Ng, 2002b).

Höök (1996) states that designers of adaptive systems face the problem of visualising the system's assumptions about users. In some AES, the system makes an assumption about the kind of user, but most of them will rely on monitoring the user's actions to provide the feedback required for creating the user model. *"Adaptive hypermedia systems are capable of altering the content or appearance of hypermedia on the basis of a dynamic understanding of an individual user. Information about a particular user can be represented in a user model to alter the information presented",* Eklund *et al.,* (1997). In some adaptive systems, students are allowed to see details held about them, making the adaptive systems scrutable (Kay and Kummerfield, 2002). In a stereotypical approach to user modelling (*Hylite+,* Bontcheva, 2002), the UM is initialised from a set of stereotypes and the system determines which stereotypes to apply on the basis of information provided by a user (such as novice or advanced user).

In some systems, the UM is created at the start of the learning process (*CS383*, Carver *et al.*, 1996, *NetCoach*, Weibelzahl and Weber 2002) and continuously updates stored information as the learner interacts with the system (*e.g., AHA!,* by De Bra and Calvi (1998), *AHM* by Da Silva *et al.,* (1998), *Interbook by* Eklund and Brusilovsky (1999), and numerous others–the majority of systems use this); while in other systems the UM is created at the end of system use (*ARTHUR*, Gilbert and Han, 1999) tracking user interests over a longer period of time (Koyshev, 2002); finally in some of them it is a mixture (*Sady*, Hothi, 1999).

The information acquired to build the UM is obtained by a variety of ways. For the UM where information is entered at the start, the students are usually asked to describe their preferences, or fill in a survey on their knowledge background and/or their browsing experience. For the UM that dynamically updates a user's preferences, the information gathered is based on the student's actions during their interaction with the system. For the UM that store information at the end of interaction, the information entered will contain both static and dynamic user details (Hothi, 1999, Gilbert and Han, 1999).

3) Adaptation Model (AM)

The adaptation model consists of an adaptation engine that is responsible for adaptation and adaptation rules. These rules determine the adaptation of content and links in hypermedia. A rule is usually of the form "If <condition> then <action>" (Wu *et al.*, 2000). A variety of adaptations have become available in the past 10 years, including adapting to the learner's learning styles {(Bajraktarevic, *et al.,* (2003), Carver *et al.* (1996), Peredes and Rodrigues (2002), Triantafillou *et al.*, 2002}; learning strategies (Bull, 2000), Hsiao (1997), reading speed (Ng, 2002), knowledge state (De Bra and Calvi, 1998, Brusilovsky *et al.,* 1998), reading behaviour (Bontcheva, 2002), browsing behaviour (Brunstein *et al.*, 2002) and prior knowledge (Weibelzahl and Weber 2002).

2.7. Previous efforts on adapting educational hypermedia

Adaptive hypermedia (AH) is one of the promising application areas for user-centred interaction techniques. Users of educational hypermedia systems will have different levels of knowledge, and different learning goals, and will want to learn at their own pace. AHS can change content, presentation or link annotation based on user models. The linking mechanism of hyperspace offers navigational freedom, but at the same time some links can be misleading in the user's search for relevant information. The user may be missing some important background knowledge that is present in the hyperspace, but not necessarily visited first. Learners need to exercise control over their learning so that its pacing and direction are guided. Mayes (1994) addressed this issue by stating the following.

> *"Interactive learning on the Web may be a way to partially supplement the classroom learning experience by providing an interactive learning environment similar to the classroom, but with more attention to individual student needs."*

As the Web becomes a more important medium for education, we need to consider how different AHS can enhance and improve the learning process.

Adapting content and links in most AHS is done in order to improve access to information, but more importantly to improve and make conceptual learning more effective. This can be achieved by allowing users to freely browse the available information, but guide them towards more relevant or appropriate material.

In the past few years there has been an increase in the construction of educational adaptive hypermedia systems. There are several examples of such educational systems. The following section will briefly discuss three selected systems that implemented a variety of the adaptive techniques included in Brusilovsky's taxonomy.

2.7.1. The AHA! approach to adaptivity

AHA! (Adaptive Hypermedia Architecture) was one of the first systems to have inbuilt adaptivity. Some of existing AHS have been motivated by it and so it fully deserves to be presented here. The adaptation in this system is provided in two forms: adaptive content and adaptive linking. AHA! provides adaptive link presentation through link annotation, link hiding and link removal. The core of AHA! is an adaptive engine that maintains a user-model based on knowledge about concepts.

The adaptive "engine" determines which fragments are shown and which are not. AHA! uses HTML pages that contain all fragments and "conditionals" to determine which fragments to show. The AHA! system associates zero or more concepts (but typically one) to a page. AHA! implements adaptive content by means of conditional (possibly nested) fragments such as:

<!--if prerequisite concept is read -- >
present this chunk of information
< -- else-- >
present some other fragment
<! –endif-- >

In the current AHA! version knowledge is only "generated" if a page is read when the prerequisites are satisfied. Instead of using a *set* of concepts as prerequisite knowledge, each page depends on a *requirement* that is a Boolean expression on concepts. Through the use of *and*, *or*, *not* and arbitrary parentheses a rich collection of requirements can be formulated.

Apart from using content adaptation, the system uses adaptive linking techniques, such as link annotation (achieved by using different colours for links), link hiding (changing the colour of 'undesired' links to black), and link removal (achieved by turning anchor tag into conditional text). The user model in AHA! is maintained based on the student's interests and the results of rules activated by the adaptive engine on user events (such as page access) . This is an example of an overlay user model, where student's knowledge is represented as a subset of expert knowledge (Carr and Goldstein, 1977; *ISIS-Tutor*, Brusilovsky and Pesin, 1994). The concepts applied in AHA have been used as educational application such as the courseware on Hypermedia Structures and Systems (*2L670* by De Bra, 1997). This system tracks student progress and based on that, generates document and link structure adapted to each particular student. Links to nodes that are no longer relevant or links to information that the student is not yet ready to visit are either removed or displayed as normal text. Similar applications of this system are found in *2L690* (system for learning hypermedia structures and systems) and *2M350* as a system for learning about graphical user interfaces (De Bra and Calvi, 1998).

2.7.2. The Interbook approach to adaptivity

Interbook (Brusilovsky *et al.,* 1998) is an example of a system that combines different adaptation methods. For each section, a list of concepts related with this section is provided. Each concept can be either an outcome concept or a background concept. The links in *InterBook* are provided from each textbook section to corresponding glossary entries. These links are generated 'on the fly' based on the student's current state of knowledge represented by the user model. *InterBook* uses coloured bullets and different fonts to provide adaptive navigation support (Figure 2.2). The font and colour of the bullet next to the link will inform the user about the status of the destination node of the link. *InterBook* integrates three methods of link annotation: history-based, knowledge-based and prerequisite-based. A green bullet and bold font means *'ready and recommended'*, *i.e.*, the node is ready-to-be-learned but still not learned and contains some new material. A red bullet and an italic font warns about a not-ready-to-be-learned node, while white means 'clear, nothing new', *i.e.*, all concepts presented in the node are known to the user. Violet is used to mark nodes that have not been annotated by an author. A check mark is added for already visited nodes.

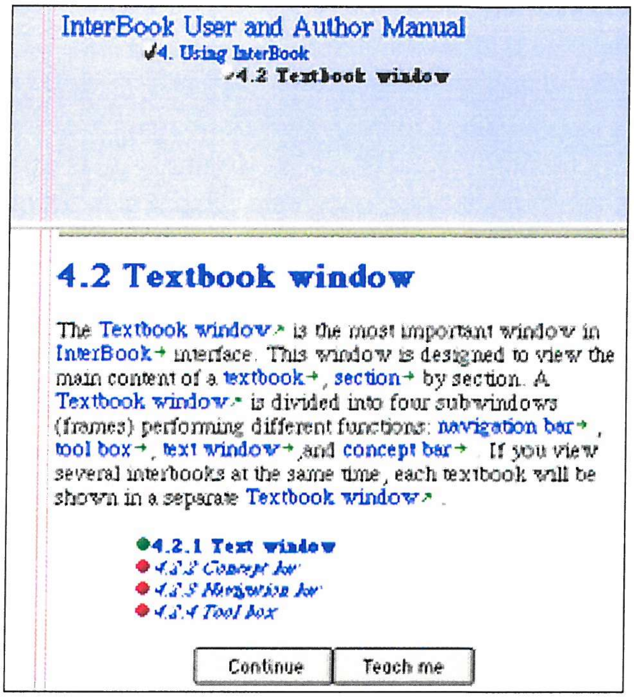

Figure 2.2. Interbook interface layout

The user model in Interbook is initialised at the start from the registration page using a stereotype model. It is continuously updated as the user interacts with the system. The Interbook approach to adaptivity was implemented and evaluated in several systems, such as *ISIS tutor* (Brusilovsky and Pesin, 1998), ELM-ART (Weber and Specht, 1997) and ACT-R (Brusilovsky and Anderson, 1998). The ELM-ART study demonstrated that both adaptive guidance and adaptive navigation support based on Interbook approach are efficient.

2.7.3. The AHM approach to adaptivity

AHM (standing for Adaptive Hypermedia Model)(Da Silva *et al.,* 1998) is an adaptive hypermedia system based on concepts, which are explained by documents. Some concepts are linked to documents and other concepts through links. The user is guided towards appropriate documents based on information about his knowledge of each concept. The AHM system adopts an approach in which users are exposed to relevant and irrelevant information. However, Da Silva *et al.* (1998) asserts, "if the user is left completely free to explore the hyperspace according to his preferences and needs, it may be more difficult for him to learn efficiently". In this view, it is interesting to have an interface that takes into account the user's goals and presents information in a relevant, non–linear order to promote efficient learning. AHM combines a more direct tutor-centred style of a traditional AI based system, with the flexible student centred approach to browsing. Link adaptation in AHM is achieved through link hiding. For that purpose the authors of the AHM system rely on typed nodes and weighted links to present the structure of the domain. The authors have *concepts* and *documents* as nodes; and as links they have *relationships* between nodes, which have an associated weight, *threshold* for concept-concept relationships and *difficulty-level* for document-concept relationships. Links are typed and represent semantic relationships between nodes. Each document has an associated *level of difficulty* with respect to the concept it explains, which varies from *0* to *99*, where a higher value means '*more difficult*'. The *documents* are multimedia objects, such as text segments, figures or interactive demonstrations whose URL is stored in a database. A document may be related to more than one concept. Each page contributes a fraction (percentage) of the knowledge of the concept. In this system concept names are converted to knowledge values in terms of percentage.

Summary

This chapter presented an overview of the history of hypermedia and the need for adaptive hypermedia in education. It examined the existing adaptation techniques, terminology and approaches to adaptation, used in pioneering and recent adaptive educational systems. In the next chapter a literature review covering learning styles, their evolution and important aspects of learning style adaptation are presented.

Chapter 3. Literature review of learning styles research

3.1 Introduction

This chapter provides a background of different theories that have been developed to explain why some students learn best when using learning materials presented in one way, while others learn better using a different kind of presentation. Such preferences are normally referred to as *learning styles*. The chapter also reviews the historical applications of the way in which such understandings have been applied in Computer Assisted Learning (CAL) context and an overview of the instruments used to measure learning styles. The chapter concludes with a few examples of AES (Adaptive Educational Systems) embedding learning styles within adaptive hypermedia learning environments.

3.2. History of development of learning styles

The following historical perspective will provide an overview of the literature, revealing an array of terms and concepts related to different preferred ways of learning. The notion that one's approach to learning can be categorised into a finite set of styles started with the work of Jung as early as in the 1920s (Jung, 1926). The concept of learning styles became popularised following the work of Curry (1990) and Dunn (1996) among others.

Considerable confusion appears in the literature concerning the terms *cognitive style* and *learning style.* An overview of literature reveals an array of classifications, and terms of learning and cognitive styles are often used interchangeably. Keefe (1979) defined cognitive style as 'preferred way of processing information' and learning style as a "preferred conditions under which information is received". According to Schmeck (1988), "learning style is a predisposition on the part of some students to adopt a particular learning strategy regardless of the specific designs of the learning task". Kolb (1994) defines learning styles as the "various methods individuals have for perceiving and processing information while reacting to their environment". They affect how people acquire and organise information. The learning styles encompass cognitive, affective and psychological components (Reiff, 1992). Paterson and Rosbottom (1995) defined learning styles as a "predisposition to behave in a particular way when engaged in the learning process". In this thesis we shall use the term learning style as a broader term than the cognitive style, to describe a set of "...traits that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Keefe, 1979).

The exploration of learning styles began in the 1970s with Witkin (Witkin, 1976, 1977), who realised that people do not learn in the same way. Pask's research in the 1970s (Pask and Scott, 1972; Pask, 1976) uncovered characteristics of concepts such as knowledge structuring, conversation theory and learning strategies. His work suggested that matching and mismatching teaching methods with a learner's preferred learning approaches has considerable effect on learning. Decades later, the theory that postulates that students taught in their specific learning styles learn with ease, master subject quickly and retain studied material for longer periods of time emerged (Dunn and Dunn, 1989).

The conceptual basis of learning style research was established when researchers reported that academic achievement was enhanced when 'teaching styles' were matched with the student's learning styles (Dunn and Dunn, 1978). The whole prospect of matching teaching methods with the preferred from of learning by an individual seemed very promising. Curry (1983) used an 'onion' metaphor to describe learning styles. The layers of the onion include the following dimensions:

personality dimension (the inner core), information-processing dimension (relatively stable layer) and instructional preference dimension (context dependent layer). The taxonomy of learning styles developed by Curry (1983) used the concepts of learning styles, student achievement, and motivation to explain the process of learning. Curry's taxonomy (1983) seemed to suggest that motivation, learning styles, learning strategies, and student learning outcomes are associated. This metaphor does not take into account any overlap among approaches. Dunn and Dunn (1978) believe that learning style reflects the manner in which elements of five basic stimuli affect an individual's ability to perceive, interact with and respond to a learning environment. These are environmental (noise level, light, temperature), emotional (motivation, persistence, responsibility), sociological (presence of authority figures, learning in varied ways), physiological (perceptual, time, mobility) and psychological (global versus analytic, impulsive versus reflective, hemispheric response patterns).

Apart from Curry's taxonomy, a review of literature shows that there are many approaches or models of learning styles, and they tend to fall into one or more of the following categories: the personality model, the information–processing model, the sociological model, the environmental and physical model. A brief description of each model follows.

The personality model or Jung's (in Kolb, 1984) model of psychological types deals with the mode of relating to the world (extroversion-introversion), the mode of judging (thinking-feeling), the mode of perceiving (sensation-intuition) and the mode of decision making (judging-perceiving) personality characteristics (Jung, 1971). An example of translating this model into practical instruments is an MBTI (McCaulley, 1990) or Myers-Briggs type indicator instrument. Another practical use of Jung's theoretical model was created by Kolb (1984), who divided psychological types into four: diverger (dominant learning mode of concrete experiences and reflective observation), assimilator (dominant learning mode of reflective observation and abstract conceptualisation), converger (dominant learning mode of abstract conceptualisation and active experimentation) and accommodator (dominant learning mode of concrete experience and active experimentation). These types of learning styles reflected preferences on how information is grasped and how information is transformed into meaning.

The information-processing model deals with the way students process information. Examples include the field dependent/independent dimension (Witkin 1977) and Dunn and Dunn's three scales: global/analytic, impulsive/reflective and left/right of brain responses (Dunn & Dunn, 1978).

The sociological model deals with preferences for working in a group or alone. Examples include Hruska-Riechmann & Grasha's (1982) learning styles scales which included: dependent, independent, collaborative, competitive, participant and avoidant learning patterns.

The physical model categorised learners according to sensory modalities such as visual, auditory, tactile and kinaesthetic (Grinder, 1991).

The environmental model deals with environmental conditions conducive to learning such as bright versus dim light, sound versus quiet, formal versus casual furniture design and warm versus cool classroom conditions (Dunn *et al.,* 1989).

Additionally, there is Gardner's multiple intelligence theory (Gardner, 1987) that divides learners according to seven intelligences: (1) verbal-linguistic (sensitive to the meaning and order of words), (2) musical (sensitive to pitch, melody, rhythm and tone), (3) logical-mathematical (able to handle chains of reasoning and recognize patterns and order), (4) spatial (perceive the world accurately and try to re-create or transform aspects of that world), (5) bodily-kinaesthetic (able to use the body skilfully and handle objects adroitly), (6) interpersonal (understand people and relationships), or (7) intrapersonal (possess access to one's emotional life as a means to understand oneself and others). Gardner, however, made a clear distinction in saying that these are intelligences, not learning styles.

There are so many defined learning styles, that it would be impractical to address all of them simultaneously. Different researchers point out different aspects of the styles. An extensive review of all learning style inventories and approaches is beyond the scope of this thesis. Categorisation of learning style approaches in this research is intended to show overlap and compatibility among learning style models and improved learning.

Individual differences in processing information are an important factor in hypermedia research, in terms of the way the designers of hypermedia software make connections and links between different pieces of information. A central theme of this chapter is the description of the information–processing model of learning styles. Various nomenclatures have been used to describe this particular dimension of the learning styles, such as wholist/analyst (Kirby, 1988), serialist/holist (Pask, 1972), field-dependent/field-independent (Witkin, 1976). The wholistic–analytic dimension defined by Riding and Douglas (1993) deals with whether an individual processes information in whole or in parts. Riding and Cheema (1991) have categorized these two style types in very broad terms: Wholist-Analytical, which describes how an individual processes information and 'Verbaliser-Imager', which describes how an individual represents information. According to them, wholists tend to view a situation as a whole, while the analytics tend to view a situation as a collection of parts. Jones and Kwok (1995) say that 'serialism' may be defined as "the acquisition of information in a hierarchical, step-by-step sequence, and holism as an exploratory approach". Table 3.1 summarises Pask's description of both types of learners.

Holist learners	Serialist learners
They learn in layers.	Prefer to learn just essential facts, sequentially ordered, related by simple links
They prefer an overview of where they are going first before learning a complex process.	Find introductory overviews distracting and confusing.
Focus on 'global' approach, synthesize broad overviews into which details may be fitted	Focus on 'local' approach, concentrating on specifics, which may lead to the emergence of the overall picture
They enjoy having examples shown to them even if they are not capable of imitating the skill yet.	They prefer to proceed step-by-step, in an orderly way, to the end result
Holist learners sometimes get confused by step-by-step instructions, especially if the steps are numerous and complex, use 'globetrotting' strategies	Serialist learners like to use a simple step-by-step strategy
Thrive on having anecdotes, illustrations and analogies	Regard anecdotes, illustrations and analogies quite distracting

Table 3.1. Characteristics of learning preferences (Pask, (1967) cited by Clarke (1993))

Felder (1988) defined 'global' and 'sequential' learning styles as a dimension with respect to how understanding of information is acquired, *i.e.,* whether in a linear (sequential) or non-linear (global) order. This terminology will be adopted in this thesis. Clarke (1993) pointed out that many of these styles 'differ more in name than nature' and that they 'can be classified into either a preference for a reasonable degree of structure and guidance (serial) and a preference for considerable freedom to explore (holistic)'.

The interpretation of this (global/sequential) dimension of learning styles has been viewed in different respects within hypermedia environments, such as structure or process. Different researchers emphasize different aspects of learning styles. Because of the way different users perceive and process information, the contents of a hypermedia system can be organised in such a way that users have greater benefits from using hypermedia. Having identified the difference between learning styles, there is a possibility of matching the layout, the conceptual structure and the choice of presentation of hypermedia materials with global-sequential learning preferences, and as such create supporting environments that can facilitate enhanced learning. The next chapter will attempt to define and consider the design of hypermedia system from the perspective of the learning and cognitive processes engaged by learners. Special emphasis will be given to the representation of learning styles.

3.3. Application of global and sequential learning styles in education

Learning styles appear to have a role to play in whether or not learners succeed in hypermedia based environments. In order to create a link between learners and learning without difficulty, a new process of matching the instructional mode to the one that learner prefers emerged. Gordon Pask's research on matching and mismatching of teaching material and types of learners shows that students learn faster and more effectively where a match occurs (Ford, 1985). Similarly, Felder and Silverman (1988) have found that the mismatch between the prevailing teaching methods and the learning styles of most of the students have several serious consequences. They developed a model of learning and teaching styles that applies well to students in technical disciplines. The idea was not to teach students according to their individual preferences, but finding a balance in instructional methods. Davidson *et al.* (1999) designed methods of helping global students and he suggests that in order to support global lessons it is important to provide an overview before presenting the steps, to establish context and relevance and offer freedom to attack issues from different angles. Whitefield (1995) produced guidelines for teaching global and sequential students. Groat and Musson (1995) state that the global students learn by examining overall results between the lesson and all its component parts. Then they analyse the end product so that they can see the relationship. The authors recommend that for such students, courseware authors should avoid presenting too many facts directly; instead direct them to unravel the information themselves. Using graphics and illustrations would help them map out new information.

Jones *et al.* (1987) created a learning preference theoretical model for holist/serialist (very similar to global/sequential dimension described in this thesis) dimension in which they suggest courseware that consists of the smallest amounts of information called 'packets'. These packets would be linked together to form courseware modules and allow progression through material in a totally serialist or global approach. The learners would be free to flip between the serialist and holistic study modes. The students would be expected to answer a multiple-choice questionnaire and failure to produce correct answers would trigger recommended packets of study. From the literature review on research regarding learning styles, the following learning style preferences or tendencies were identified:

Global learning preferences: $U_{G/H}$	**Sequential or analytic learning preferences: U_S**
Attention towards scanning [Kirby, 1988]	Focused attention. Tend to notice and remember details [Kirby, 1988]
Organisational schemes involve more random or multiple accessibility [Kirby, 1988]	Interest in operations and procedures [Kirby, 1988]
Heavy dependence on structure and guidance [Clarke, 1993]	Prefer to have minimal structure and guidance [Clarke, 1993]
Tend to read pages by 'globetrotting' around in haphazard manner [Pask, 1976]	Prefer step by step sequential organisational schemes [Kirby, 1988]
Prefer having examples [Pask, 1976]	Focus on specifics that lead to an emerge of overall picture [Clarke, 1993]
Prefer to learn in hierarchical manner (top-down) [Pask, 1976]	Learn in a sequential fashion, a step at a time [Pask, 1976]
Seeing similarity between different experiences [Kirby, 1988]	Seeing differences in apparently similar experiences [Kirby, 1988]
Learners are linear and orderly, learn in small incremental steps [Felder, 1988]	Learners are holistic, system thinkers who learn in large gaps [Felder, 1988]

Table 3.2. Characteristics of global and sequential learning preferences

3.4. Hypermedia linking mechanisms

It has been derived from the literature that there are two principal considerations in designing hypermedia courseware to accommodate preferred learning styles: the way in which the information is formatted and how an individual processes the given information. One direction of research focuses on how the students perform in a hypermedia environment when the application imposes a knowledge structure of a specific topic on a learner. Another direction is examining linking structure and navigational patterns and consequentially, their effect on learning.

Hypermedia can be designed in a variety of ways. To connect information nodes different linking structures have been identified in the literature. Examples of three types of linking mechanism have been found. Graff (1999) examined the relationship between mapping 'analytic' (sequential) and 'wholist' (global) cognitive styles and three different hypertext structures. Graff (1999) suggested that individuals might benefit from hypertext structures, which are consistent with the students' learning styles and may facilitate learning. He adds 'it may be necessary to provide different linking structures to individuals of different cognitive styles, in order to make the hypertext instruction optimally effective'.

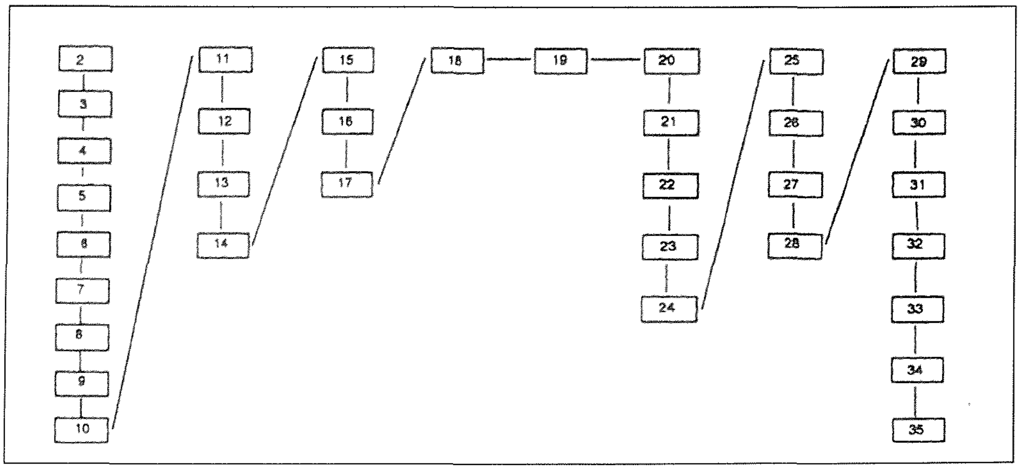

Figure 3.1. Linear linking structure–Graff (1999)

In the linear linking arrangement, the students can move to the next or previous page.

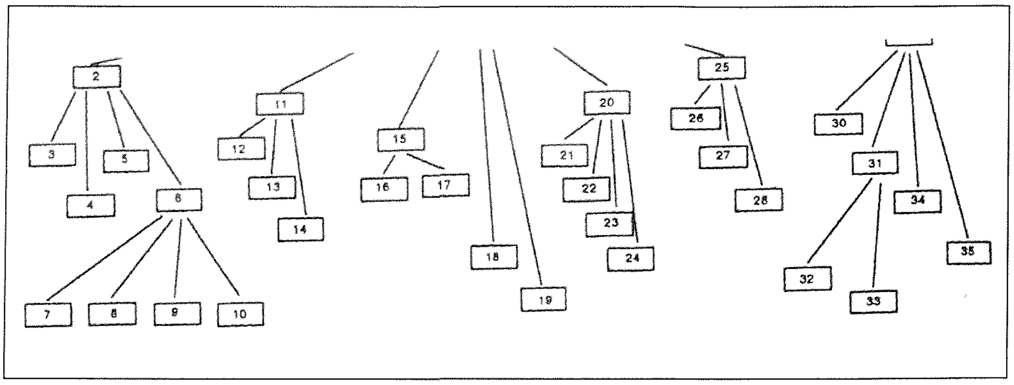

Figure 3.2. Hierarchical linking structure, Graff (1999)

In the hierarchical version the students could move from reading a page at one level, down to a page that is below it in the hierarchy, or back to a page that is above in the hierarchy.

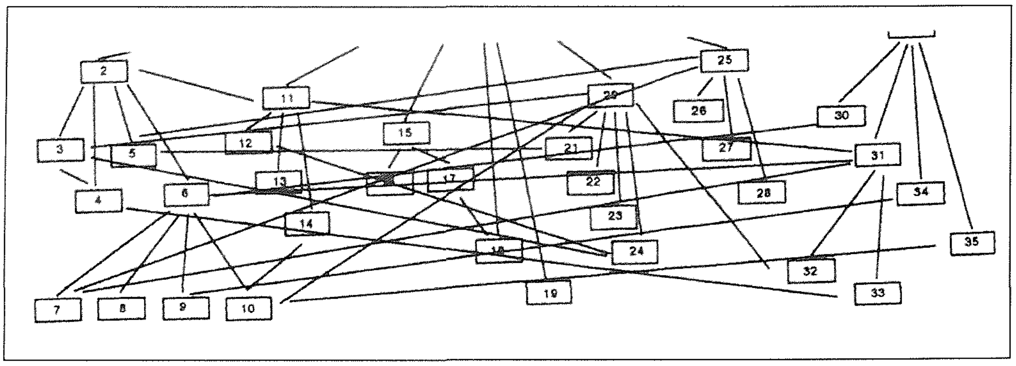

Figure 3.3. Relational linking structure, Graff (1999)

The relational linking structure is identical to the hierarchical structure, *i.e.,*, the students can move up and down in the hierarchy of pages, with the addition of additional links that allow the student to move to other page locations within the structure. Graff (1999) found that 'wholists' benefited from courseware if the model of delivery provided an organisational aid to learning. When the courseware was less structured and the learners had to provide the organisation, such an environment was favourable to 'analytics'.

In another study, Oliver and Herrington (1995) suggested that hypermedia materials could be constructed so that they support metacognition (one's knowledge concerning cognitive processes, Flavell (1979)) among the students. They described three types of "hypermedia forms" as the following:

- Linear linking, where the links are minimal and act to connect nodes in a specified sequence
- Hierarchical linking, where the students are given more freedom in the choice of path through learning materials
- Referential linking, where the students are free to move among nodes and where very little structure is evident (Figure 3.4)

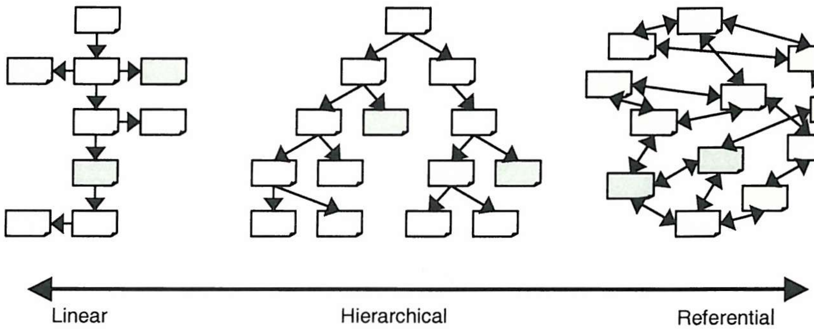

Figure 3.4. A continuum describing linking in hypermedia: Oliver and Herrington (1995)

Ford and Chen (2001) have structured learning materials in a hypermedia system, so that they match a 'breadth–first' structure that corresponds to holist style and a 'depth-first' sequence that matches a serialist learning style. The 'breadth-first' structure allows the students to perform a top-down approach of learning, where an overview is first established, before attending to the details.

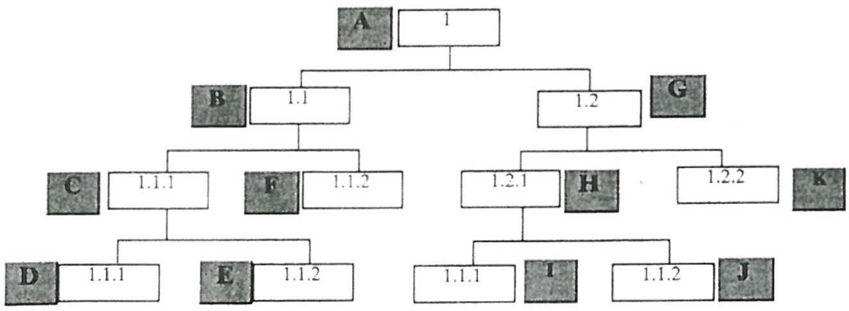

Figure 3.5. Ford and Chen (2001) 'depth-first' linking structures

On the other hand, the 'depth–first' structure allows the students to adopt a 'bottom-up' approach, where attention is paid to details, while the bigger picture, or an overview, is built up later in the process.

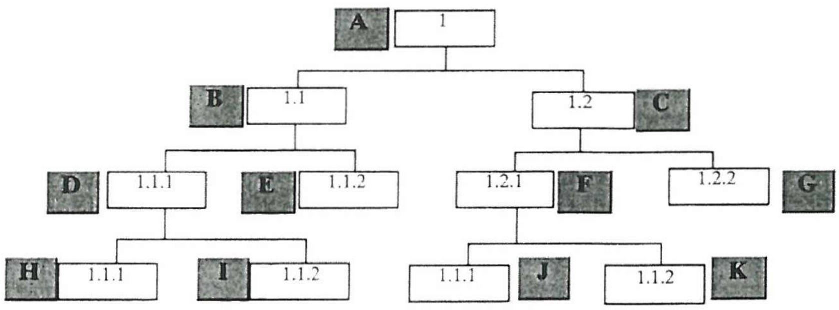

Figure 3.6. Ford and Chen (2001) 'breadth-first' linking structures

3.5. Learning style measurement instruments

In the 1980s a number of questionnaires to analyse and define preferred learning styles was produced. The debate over the definitions and validity of learning style concept and such questionnaires is still present. A small selection of instruments most frequently used in hypermedia applications is presented below, with a brief commentary of each.

Kolb Learning Style Inventory (LSI): Kolb's (1984) LSI measures learning styles as a combination of preferences for each part of the learning cycle (active experimentation, concrete experience, reflective observation, abstract conceptualisation). Kolb's inventory consists of 48 statements, which are ranked in order of preferences from 1 to 4 (1 is 'least like me', and 4 'most like me'). Learners, according to Kolb can be categorised as Divergers, Assimilators, Convergers or Accommodators.

The Index of Learning styles (ILS): This is a questionnaire developed by Felder and Soloman (2001). It comprises of four scales of learning: Active and Reflective learning (the processing dimension), Sensing and Intuitive learning (the perception dimension), Visual and Verbal learning (the Input dimension), and the Sequential and global learning (the Understanding dimension). This implies that the students preferentially take in and process information: whether it is by seeing, hearing, analysing, visualising, reasoning logically and intuitively, steadily and in 'fits and starts'. The questionnaire comprises of 44 items, 11 on each of the four scales. The strength of preference varies from 1-3 for fairly well balanced on the two dimensions, 5-7 for a moderate preference (the student will learn more easily in a teaching environment that favours that dimension) and 9 to 11 that describes a very strong preference for one dimension of the scale. This implies that the student with such preference may have difficulty learning in the teaching environment that does not support that preference. The questionnaire has been tested on engineering students at Caroline University. Felder sees learning styles as characteristic strengths and preferences in the ways the students take in and process information (Felder, 1996). The Felder Silverman questionnaire describes Pask's serialist/holist or sequential/global dimension best in terms of an "understanding" dimension and suggests that it could be incorporated in instructive material to enhance the student learning.

There are obvious implications for teaching students with such preferences. "To support global learners it is important to provide an overview before presenting the steps, to establish context and relevance, and offer freedom to attack issues from different angles. This is one area in which well-designed educational software may be more powerful than printed or video material", Davidson *et al.* (1999). Felder's model was developed with the intention of not necessarily teaching the students exclusively according to their learning style preferences, but to "strive for a balance of instructional methods." Felder (1988) describes sequential learners as linear and orderly, who learn in small incremental steps and global students as holistic, system thinkers who learn in large gaps.

Honey and Mumford's Learning Styles Questionnaire (LSQ) (1992): This instrument has four major classifications of learners: Theorist, Reflector, Pragmatist and Activist. The questionnaire comprises of 80 questions and learners tick statements with which they agree. Learners can have very weak, weak, strong and very strong preferences for each of the four learning styles.

Riding (1991) Cognitive Style Analysis (CSA): This test is a computerised test that measures the verbaliser-imager (VI) and the wholist-analytic dimensions (WA) of cognitive styles. The VI dimension indicates whether the student tends to represent information verbally or in mental pictures. The WA dimension is indicative of whether the student tends to organise information in whole or in parts.

There are more than a dozen other learning style associated instruments available, but their review is beyond the scope of this document. A more thorough review can be found in Bradbeer (2002) who has prepared the most recent review of the instruments used to assess learning styles.

3.6. Investigating the effect on learning outcomes by matching learning style preference

Individuals' differences in learning preferences have an influence on their responses to information presented in different ways. The notion that one's approach to learning can be categorised into a finite set of styles attracted the attention of educators who started exploring and embedding learning styles into educational courseware. Educators have tried to identify and address the differences through a variety of available media, ranging from printed text through to computer-based applications, with the aim of enhancing student learning. A number of experiments were conducted to examine global/sequential dimension, combined with the verbal-images dimension (Riding and Grimley, (1999), Riding and Caine (1993), McLoughlin (1999), and Pillay and Wills (1996).

However, there are many practical difficulties in catering for learning styles, as mentioned in Clarke (1993). The first issue is the sheer number of them. Curry (1990) observed the weaknesses of learning styles concept, such as definitions, validity of learning styles and the identification of relevant learning style characteristic in educational context. Another difficulty in designing hypermedia software that incorporates learning styles is the representation of the styles in the hypermedia environment. The literature reveals that there have been very few studies, which have set out specifically to investigate the relationship between learning styles and hypermedia applications, especially in adaptive hypermedia software. The following section presents a few examples of the application of learning styles in CAL context.

Kwok and Jones (1985) carried out an experimental study with a computerised 'front-end' study preference questionnaire (based on Ford, 1985) in order to suggest to the student a suitable navigation method through the system. They found that the students at the far extremes of the learning style spectrum needed the navigational guidance, and it helped raise their interest in the material. Pillay *et al.* (1996) reported the study where the students with wholist/analytic cognitive style received instruction that matched and mismatched their style of learning. Students' styles were analysed using CSA (Cognitive Style Analysis) software (Riding 1991). They had two studies, applying verbaliser, imager, wholist and analytic matrix dimensions of learning styles. They used a mix of images, text and advanced organisers as representational elements of the above-mentioned matrix of learning styles. The matched group performed better in the explanation and problem solving tasks.

Riding and Sadler-Smith (1992) investigated an interaction between the mode of presentation and style and their effect on learning performance. They believed that structure and organisation of the contents might interact with the wholist/analytical dimension of style. Their conclusion was that the mode of presentation has important effects on learning performance. They found that learning performance, amongst secondary school students, was affected by the representation of learning styles in terms of instructional material treatment, abstract and pictorial presentation. The study employed courseware presented in a variety of modes of presentations (visual–verbal) with different organisation and structure of content.

Ford and Chen (2001) explored the relationship between the match and mismatch of instruction presentation style using the student's style of learning (field dependent and field independent). They have found significant differences in performance regarding conceptual knowledge for the students under two different conditions.

Graff (1999) tested the relationship between three different hypertext structures (linear, hierarchical and relational) and the performance of the students with *wholist-analyst* styles. He suggested that providing different linking structure to individuals of different styles would make the learning from hypermedia more effective. No significant differences on recall of information were found.

Felder and Silverman (1988) have synthesised the findings from a number of studies to formulate a learning styles model with dimensions that should be relevant to science education. The global and sequential classification schema refers to the way information is acquired by students. For sequential students they say that they absorb information and acquire understanding of material in small-connected chunks, and they may lack a grasp of the big picture. For global students Felder and Silverman (1988) say that before they can master the details of a subject they need to understand how the material being presented relates to their prior knowledge and experience. They suggest using analogies and illustrations as a method of teaching global students. Also, for such students it is important to point out connections between current material and other relevant material. For sequential students, on the other hand, it is important to demonstrate the logical flow of individual course topics. The Felder and Silverman learning styles have been incorporated in a number of applications: sensing-intuitive dimension by Paredes and Rodrigues (2002), the sequential-global dimension by Carver *et al.* (1996) and Montgomery and Groat (undated).

Carver *et al.* (1996) created a system that would enhance the student's learning based on a variety of learning styles. The system consists of a range of tools. The students were allowed to traverse the course material according to their own unique preferred ways. The course was based on a Felder (1988) learning style model, which divides learning styles into four categories: active and passive (define how information is processed), sensitive and intuitive (define how information is perceived), visual and verbal (define how information is received), and global and sequential (define how information is acquired) category. Only

Carver's paper couples Felder's learning styles with adaptive hypermedia to provide a tailored lesson. In this system adaptation is achieved by dynamically creating pages with a list of course elements in a sorted order. With this approach the key was to determine what media type (graphics, sound files, text, movies, slideshows) are appropriate for different learning styles. Jonassen (1988) extends learners individual learning approaches to learning through adaptive systems.

3.7. Previous efforts on adapting learning styles

This section describes the attempts made to embed learning styles within adaptive hypermedia learning environments, by adding some adaptivity and intelligence to the software, and individualising instruction. There are several such examples of adaptive web-based educational systems that have employed learning styles, such as AES-CS, CS383, INSPIRE, iWEAVER ARTHUR, TANGOW and MANIC system. Given the complexity and scale of these systems, complete details of each system will not be given, but their features will be summarised below. These systems incorporate learning styles into their adaptation.

3.7.1. AES-CS approach to adaptivity

AES-CS (**A**daptive **E**ducational **S**ystem based on **C**ognitive **S**tyles) (Triantafillou *et al*, 2002) deals with the field dependent (F.D)/field independent (F.I.) dimension of learning styles (Witkin *et al*, 1977). Witkin defines it as the aptitude to take into account a full set of data (F.D.), or the aptitude to analyse each component of a whole (F.I.). Whereas field-dependent student see things in the entire perceptual field (see the forest from the trees), field-independent learners see the tree within the forest. The authors in AES-CS adapted the two different learning approaches by provision of advanced organisers, maximum instruction and feedback, and more structured lessons for field dependent students. The authors also provided more control with minimal instruction and feedback for field independent students. The student profile consisted of three parts: personal, including static data such as name and password; cognitive, including cognitive style preferences (field dependent of field independent); and knowledge, containing a list of learned concepts (concepts: known, unknown, learned, and well learned). Adaptation presentation and navigation support techniques were used to provide adaptation according to their cognitive style and knowledge state. Conditional text techniques were used to present information in different styles and link annotation was used for link selection. A blue colour was used for 'recommended' and grey for 'not ready to learn' type of guidance. In addition, the knowledge state was also annotated using differently coloured 'checkmarks' to indicate what was learned or well learned. Another feature of this system is that the students have the ability to change the control options, such as amount of feedback and instruction as well switch between two cognitive style dimensions. In this system a student is given a control of their preferences as they interact with the courseware and as such would suit so called 'versatile' students.

3.7.2 CS383 approach to adaptivity

CS383 (Computer Systems 383) system (Carver *et al.*, 1996) is an adaptive web based system that adapts instruction based on the Felder Silverman learning styles model (global-sequential, visual-verbal, sensing-intuitive, inductive-deductive).

This is one of the early adaptive systems that tailored presentation to a group of students. The courseware is written in HTML and the adaptation technique used is 'adaptive presentation'. Every lesson starts with a list of objectives and is followed by several different presentations of courseware, each geared towards different learning styles. Media used to represent these styles include embedded pictures, animations and movies. The student model is obtained at the start of using the system. The students answered a survey at the beginning and lessons were presented in their preferred learning style. Common Gateway Interface (CGI) forms were used to determine students' learning styles.

3.7.3. INSPIRE approach to adaptivity

Another more recent adaptive system that incorporates learning styles is the 'INSPIRE' (an **IN**telligent **S**ystem for **P**ersonalised **I**nstruction in a **R**emote **E**nvironment) system (Grigoriadou *et al.,* 2001). The authors adopted Honey and Mumford's (1992) implementation of the system, which is based on Kolb's

(1994) theory of experiential learning (activists, pragmatists, reflectors and theorist learning styles). Inspire generates lessons that correspond to specific learning outcomes accommodating a learner's knowledge level and learning style. The domain model is structured into three levels: outcome concepts, prerequisite concepts and related concepts. Their student model consists of two parts: general information about the student (age, sex) and their current knowledge level (insufficient, rather sufficient, almost sufficient, sufficient).

As the students progress through the system, they are monitored and the student model is updated. Lessons are divided into layers and generated dynamically. The instructional outcomes are defined as three states: *Remember* (remember the most important aspects of a lesson), *Use* (ability to apply knowledge to specific cases), and *Find* (ability to generate new generalities). There is also a presentation module responsible for modifying the appearance of knowledge modules.

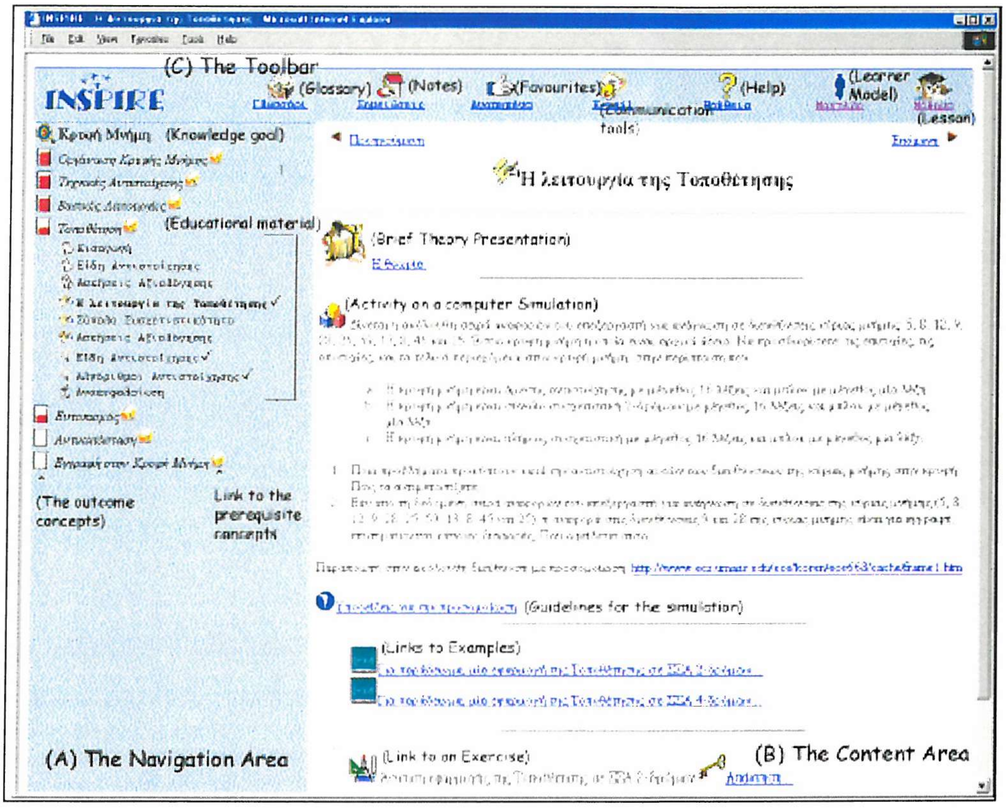

Figure 3.7. INSPIRE's main screen, (Grigoriadou *et al.* 2001)

The authors use both adaptive presentation and navigational support (AP and ANS). Adaptive presentation is applied by ordering the presentation of the knowledge modules. The information presented is divided into example–oriented (example and theory) and activity-oriented (computer simulation) information to cater for the activist-reflectors dimension of learning styles.

Adaptive navigation support is implemented by annotating the links in the 'navigational' area of the system. Differently coloured icons placed next to links also help the students by indicating concept prerequisites. Student progress is indicated in metaphoric form (a filling glass). The links recommended by the system change from black and white to coloured. Coloured icons accompany the links that lead to the material that the system proposes the learner to study next. The system is implemented using IIS web server. The student model and metadata describing instructional material are stored in an SQL database. Lessons are dynamically generated using Active Server Pages.

3.7.4. ARTHUR approach to adaptivity

ARTHUR (Gilbert and Han, 1999) is an adaptive learning system that adapts instruction to accommodate learning styles, such as the visual-interactive style, the auditory-lecture style and the text style. For example, the auditory style uses streaming audio and video to present a general explanation of each concept followed by examples. The system consists of learning modules and each module begins with concept1 and ends with concept4. The system attempts to emulate "many-to-one" relationships between instructors and learners. It uses mastery learning to adapt instruction for each learner. For instance, if the learner scores 80% or better, the student can move to the next module.

The user model in ARTHUR is created after the student completes a course. The user model contains each concept that the learner passed or failed. The user model is also used when previous learners return to take a similar course when assigning instruction methods. In addition, Arthur makes use of an intelligent dbase of (frequently asked questions) or FAQs to allow students to pose questions about concepts and provide them with a quick and effective response. The intelligent FAQ system is based on query strings. ARTHUR is available as a web based system. It uses a complex SQL knowledge database on a web server. Arthur is accessible via an Internet browser on a client computer. The java applet in the browser communicates with the knowledge base in order to provide instruction.

3.7.5. iWEAVER approach to adaptivity

iWeaver (**I**nteractive **W**eb based **A**daptive Learning **E**nvironment) (Woods and Warren, 1995) is another web based adaptive learning system that creates an individualised learning environment accommodating specific learning styles. The learning style model used is the Dunn and Dunn model (auditory, visual, kinaesthetic etc.). The adaptation is achieved by providing different media representations for each student. The system offers a variety of adaptive responses, which include multimedia representations to accommodate different learning preferences.

Text based representation is achieved using variations of textual content. Auditory representation is achieved using sounds and streaming audio. To appeal to visual and kinaesthetic students puzzles, animations, drag-and drop examples and riddles were used. Impulsive students made use of Impulsive representation, which included a 'try it' button. Reflective student preferences were tailored by using a note-taking tool that allowed them to reflect on the new material. Finally global and sequential representations of learning preferences were applied by providing advanced organisers or providing the 'big picture' of where they are in the learning process. The learner model is continually revised and adapts its learning style recommendations to the learner. The student preferences vary from the perceptual (auditory, visual, kinaesthetic, auditory) to the psychological domain (impulsive, reflective, global and analytical). To predict the student's preferences a Bayesian network is implemented. This network attempts to predict the preferences based on a student's prior actions and selections. *iWeaver* currently only supports the adaptive presentation technique by varying different media representations and using conditional text with regard to the student's learning style. The system uses a variety of web technologies to achieve the adoption ranging from SMIL language, XML, ASP, Flash presentations and Database driven JavaScript pages. The student model is stored in a MySQL database.

3.7.6. TANGOW approach to adaptivity

Two learning style dimensions (sensing/intuitive) from the Felder-Soloman scale (2001) of learning styles are incorporated in TANGOW (Task-based Adaptive learNer Guidance On the Web) system (Paredes and Rodrigues, 2002). Sensing learners prefer to learn facts and procedures, while intuitive learners prefer conceptual and innovative information oriented towards theory. The adaptation in this system lies in presenting a different sequence of examples for sensing and intuitive students (examples before expositions to sensing learners and the opposite to intuitive learners). Adaptation is done to match the students' learning style preference. The students' learning styles are used as a means to improve the efficiency of adaptive educational systems. The TANGOW system adapts the content and navigational options of the courses automatically to the students' learning styles. The example used to explain the adaptation effects is taken from a chess course developed with TANGOW. In this system the exposition-exemplification sequencing for sensitive-intuitive learners with moderate and extreme learning style preferences on the Felder Soloman scale is adapted.

3.7.7. MANIC approach to adaptivity

This (Stern and Woolf, 2000) is an online lecturing system that provides adaptive content based on students' knowledge and learning style preferences. The system incorporates machine learning to predict the student's preferred learning style. Content in MANIC is organised into a network of topics, with linked prerequisites, and outcome concepts. The user model contains student's learning preferences, such as preference for graphic or textual information. The learning styles are predicted using the 'Naïve Bayes Classifier', which determines learning styles by considering a student's previous choice of learning style preference. Adaptation in MANIC is achieved by using the 'stretchtext' technique. Based on student's preferred style of presentation and mastery level of concepts, the final content is customised. This system does not infer learning style from a questionnaire, but is based on student's use of courseware. This way a more personalised way of learning was achieved.

Summary

The early part of this chapter surveyed the literature, showing the range of theories that exist to explain the different effectiveness of the interaction of different learners with the same set of learning resources. We also defined the learning styles terminology used and explained the approach relevant to the system created in this research. This chapter also presented a literature review of previous attempts investigating the effect on learning outcome by matching preferred learning styles. A variety of instruments used for examining learning style preferences are also discussed briefly. It is the view of this author that the effectiveness of hypermedia applications can be significantly enhanced if designers of hypermedia courseware modified the sequence and presentation of learning materials, to accommodate the learning styles of individual students. The next chapter will describe the implementation of LSAS. It is an adaptive web based learning system that incorporates learning styles and forms a significant building block of this thesis.

Chapter 4. Initial work: system design and architecture

4.1 Introduction and purpose of study

This chapter discusses the implementation of the system called LSAS (Learning Styles Adaptive System), offering an insight into the main components of the system and the key issues that influenced its design. From a technological perspective, issues pertaining to the implementation environment such as domain material and hypermedia environment are discussed. The purpose of building this first adaptive system was to determine what the effects of matching learning styles to a student's learning style preferences in a hypermedia environment, has on the learning outcomes. In the trials of the application the students firstly learned by interacting with a version of the hypermedia courseware that matched their learning style and secondly by interacting with a version of the hypermedia courseware that did not match their learning style. The system supports the both hierarchical and linear linking structure of content. This chapter describes an overview of the experimental design followed by the system architecture, including its main components. Finally a case study covering the system implementation is presented.

4.2. Overview of the design

From the literature review it was concluded that the learning styles are seen as a significant contributing factor in learning. In this thesis an attempt has been made to represent some of the characteristics of the learning preferences within an adaptive hypermedia environment. The sample of the students involved in this study comprised twenty-two, year-10 students (they are 14 year old students attending National Curriculum) in the first year of a two-year UK GCSE[1] geography course. They browsed through two different versions of the web-based courseware; one version matched their preferred learning style and the other did not. The two learning styles incorporated into the hypermedia courseware were global and sequential learning styles.

Both sets of courseware were part of the GCSE syllabus. The first courseware topic ("Countries of the world") was developed and adapted from a GCSE geography book (Pallister *et al.,* 2001). The instructional material for the second courseware set ("Ozone layer depletion") was a mixture of web resources. The courseware was new to the students, so interference from prior knowledge was not a concern.

Before the start of the experiment the positions of the students on the learning style dimension were evaluated using a web-based, self-administered Felder-Soloman Index of Learning Styles Questionnaire (ILSQ), that assessed four learning style dimensions: sensitive/intuitive, verbal/visual, sensitive/intuitive and global/sequential (for details on how to access the url for this ILSQ see Appendix B). Attention in this study was focused on the bi-polar nature of the LSQ scales, the global-sequential dimension. Figure 4.1 shows the ILSQ scales.

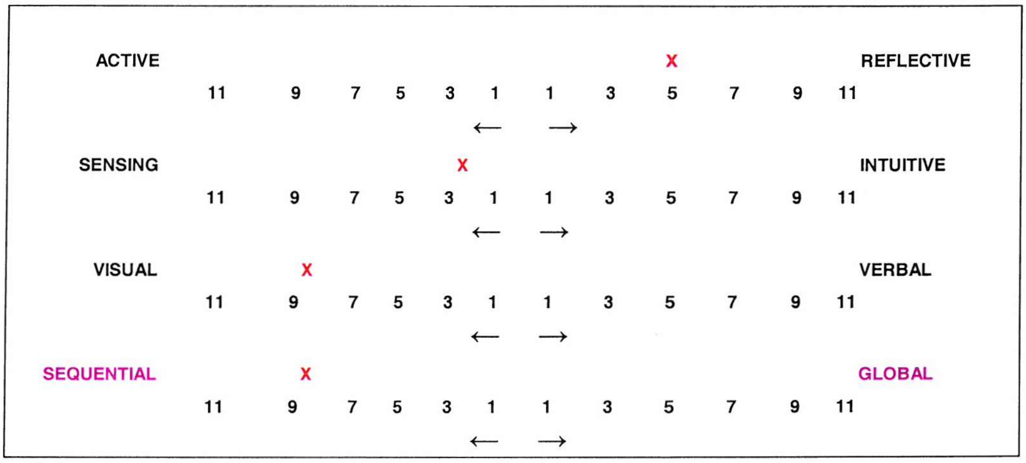

Figure 4.1. Example of learning style questionnaire (ILSQ) results

[1] GCSE denotes General Certificate of Secondary Education in the UK

At the start of the study, the students read a short explanation concerning the use of the system. They then logged onto the system and their learning styles identified in the initial questionnaire were recorded. The students then completed a pre-test on the first learning topic and then proceeded to browse and study the learning material presented in a style that matched their learning preferences. Having completed that, the students were presented with a recall-type post-test. The questions were knowledge questions, as they tested recalling of facts, terms and concepts as suggested in Bloom's taxonomy (1956).

In the second part of the study, the students logged in again, and completed a pre-test about the second subject. They proceeded to browse and study material, which was supplied in a manner that did not match their learning preference. Upon completion of the second browsing session the students completed the post-test. The two main dependent variables in this study were the achievement scores obtained in the two post–tests and the session-browsing times. For this study significance testing or 'hypothesis testing' was used. The results are presented in chapter 5.

4.3. Architecture of the system

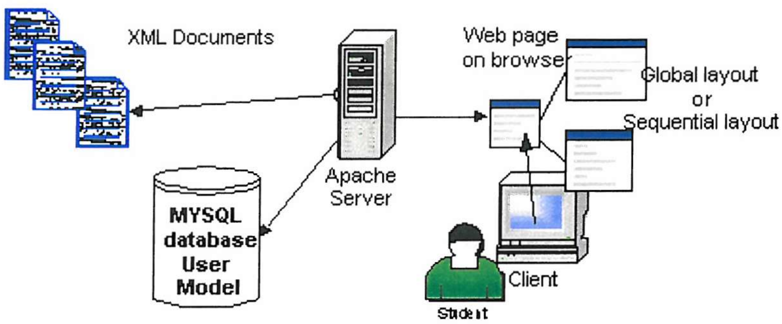

Figure 4.2. Architecture of LSAS

Figure 4.2 shows the system architecture, which was based on an Apache server. The student model is stored in a MySQL database. The courseware is stored in XML files. The students need to use a browser capable of parsing XML and XSL. No specific client side software needs to be installed on the user's PC.

In order to create the web pages and the student management part of the system, the following technologies were used: cascading style sheets, MySQL, PHP and XML. MySQL is a database management system that is very fast, reliable, and easy to use. The connectivity, speed, and security make MySQL highly suited for accessing databases on the Internet. It is a client/server system that consists of a multi-threaded SQL server that supports different back ends, several different client programs and libraries, administrative tools, and a programming interface.

PHP is an HTML-embedded scripting language. The goal of the language is to allow web developers to write dynamically generated pages quickly. XML is a mark-up language for documents containing structured information. Structured information contains both content (words, pictures, etc.) and some indication of what role that content plays (for example, content in a section heading has a different meaning from content in a footnote, which means something different than content in a figure caption or content in a database table, *etc.*). A mark-up language is a mechanism to identify structures in a document.

Using XML and XSL technology proved to assist the authoring of sessions and minimising work load, and allowed the reuse of elements. Elements for the global session such as overview, summary, 'more information', and 'next' and 'previous' links were embedded inside XML files, whilst XSL scheme files were tailored to the session type.

4.4. Case study and system components

The first step in developing courseware which provides both guided learning and free exploration is to devise a prototype for applying learning styles and enabling the students using the resulting web based hypermedia courseware to follow their preferred learning styles. The organisation of the case study in the LSAS experiment is presented in Figure 4.3.

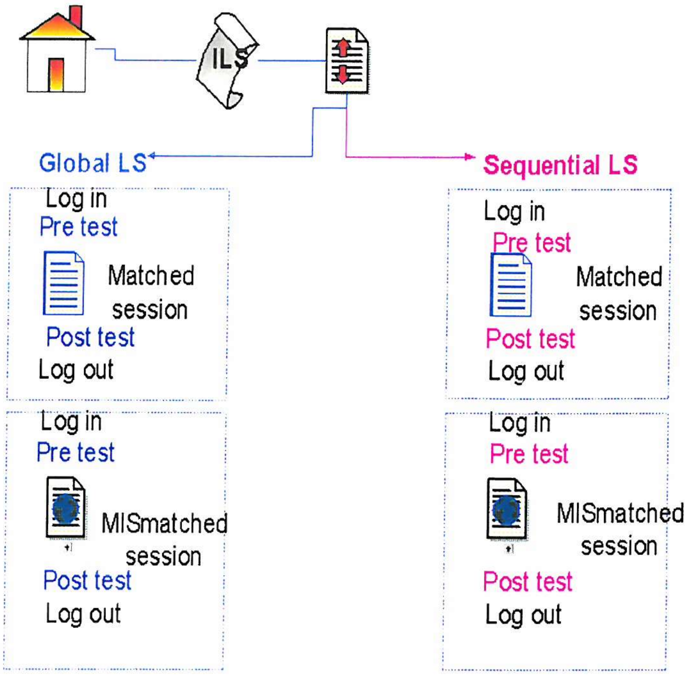

Figure 4.3. Map of the organisation of experiment

The main features of the hypermedia system LSAS are:

i. ILSQ (Index of Learning Styles Questionnaire)
ii. Logon phase
iii. Background questionnaire
iv. Knowledge pre-and post questionnaires
v. Global Session
vi. Sequential Session
vii. Attitude Questionnaire
viii. Management of the student model

Before the system can create a personalised course it must have some initial information about the student, so the student model in LSAS is created at the beginning of the system use. Static data about the student's computer competence, learning style preference and knowledge about the topic are collected through a series of questionnaires. Dynamic details such as the log of browsing history make up the dynamic or usage part of the student model. Having acquired the learning strategy preference beforehand, the courseware design is adapted accordingly, firstly to match and then secondly, mismatch the preference. The system takes into account computer competence but currently does not cater for the novice / expert stereotype. The courseware was adapted at three levels:

- Content structure and layout
- Format of content displayed
- Linking structure

i. ILSQ (Inventory of learning styles questionnaire)

For the purpose of measuring the preferred learning styles, an ILS questionnaire was used. This questionnaire was the 44-item questionnaire created by Felder and Solomon (1992)(see Appendix B, p. 179). The information obtained from the questionnaire was fed into the student profile as soon as it became available. Once the questionnaire was completed, the students were presented with an introductory page, explaining how link annotation is used and showing them the flow of study. The questionnaire provides a mechanism to record the learning style preferences of each student (global and sequential preferences in this case). This can then be used as a basis for making changes in content structure and linking mechanisms, and to update the student model accordingly. According to the ILSQ answers, the students were classified into groups as global or sequential students. The preferences on that scale ranged from 1-11 (from weak and moderate to strong preferences). The purpose of using the questionnaire is to define the student's learning styles before they start using the system.

ii. Log on phase

In order to identify the students, they needed to log on and obtain a student name and a password. This facilitated the tracking of each individual student's actions throughout each browsing session. Introductory pages explain the purpose of the questionnaire and the instructions on how to use the system. If the student has accessed the system before, the student is provided with the instructions on how to come back to the logon page. The students are informed what their task is and the tools they can use (such as search and additional information) to help them achieve their goal.

iii. Computer background questionnaire

The questions asked in this questionnaire were: previous hypermedia experience, browsing competence and confidence using computers. These and additional questions, such as the amount of time spent each day at the computer and type of browser used *etc.* (the full list of questions can be found in Appendix B), were used to assess how comfortable the students were using a web-based hypermedia system. As a preliminary example of courseware it was decided to use the case study topic of the ozone layer. The topic is taught at the GCSE-level of the national curriculum. The material used has been collected from a variety of sources and curriculum books (Fullick & Fullick, 2000, pp. 201).

iv. Knowledge pre and post questionnaires

This questionnaire was filled in before and after the students interacted with adaptive sessions. The students were expected to answer the questionnaire before reading the courseware material. This questionnaire consisted of ten fill-in-the-gap questions [2]. The post-test contained the same questions that were asked in the pre-test. If the answers given in the pre-test were correct, they would automatically appear in the post questionnaire. This would give the students the indication of whether their answers were correct in the pre-test, but also prevented the repetition of entering the same answers in the gaps. The answers that were typed in the gaps had a limited length, which was supposed to prevent the students from entering widely erroneous answers.

Accommodating learning styles

In order to accommodate global and sequential learning style preferences in a hypermedia-learning environment, we can attempt to infer the text and the student layout preference. The following features, listed in Table 4.1, derived from the theoretical research work of Pask (1976) and Kirby (1988) can be incorporated to create an application that allows an adaptation of individual learning styles.

Global students: U_G	Sequential students: U_S
Adaptive table of contents	Adaptive next /back buttons
Allow many links on the same page	Make pages short and concise
Provide summary of the document	Reduce a number of graphs
Provide overview of each page	Present info in step- by step manner
Provide additional related information	Provide minimal number of links on the page
Provide visual cues, symbols & explanations, a list of significant items, link annotation	Provide fewer links on the same page
Provide tooltips /hints/suggestions	Provide minimal guidance
Provide graphs &text illustrations	Prefer well defined layout
Present a lot of text on the page	Reduce the amount of info in a page

Table 4.1. Accommodating learning preferences in a hypermedia environment

[2] Full list of questions can be found in Appendix A

v. Global session

Based on the learning style description by Pask (1976), the following learning style representation in a hypermedia environment was compiled. The majority of these presentation elements apply to the layout, sequencing and structure, as well as the navigation of the student interface. The two principal considerations in designing hypermedia courseware to accommodate preferred learning styles are: the way in which the information is formatted and structured, and how individuals process the given information.

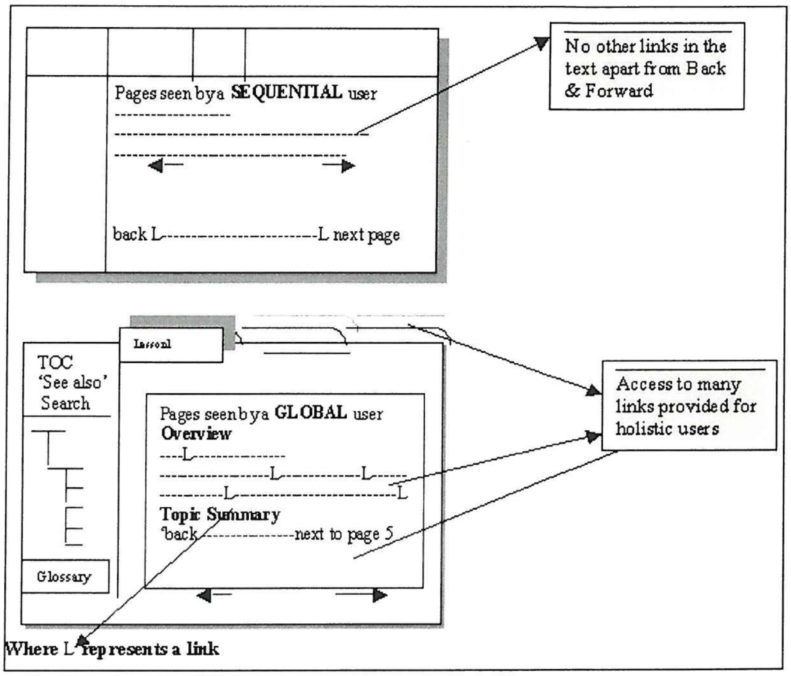

Figure 4.4. The user interface templates (sequential and global)

Figure 4.4 depicts a template of the global and sequential page layouts. The difference in presentation of the two types of formats is apparent. For the students with a global learning style preference, pages comprised elements such as a table of contents, summary, diagrams, an overview of information and a plethora of hyperlinks. For sequential students, the pages contained small chunks of information, text-only pages with a few links, such as 'forward' and 'back' begin present. The global session was organised as a set of ten lessons. The interface for all sections of the course was presented in a consistent form, allowing the students to navigate through the courseware in a 'top-down' manner. Included are icons entitled "more info" and "see also", their meaning being self-explanatory. Each page contains 'descriptors' explaining what the next lesson is about, providing ease of navigation through the system. The content material was analysed to determine the optimum structure for each learning style. Other elements incorporated in the global user interface were summaries and the "inverted pyramid" style of presentation (where news and conclusions are presented first followed by detail and background information). Figure 4.5 depicts a typical global session layout.

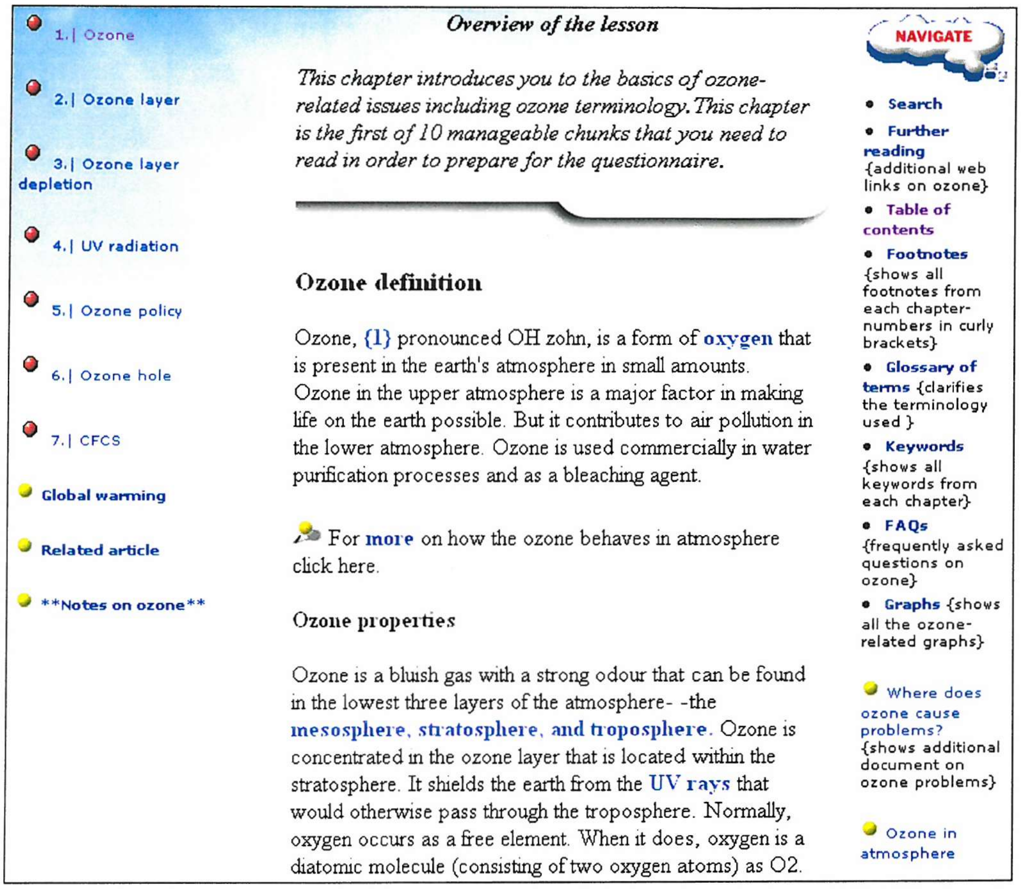

Figure 4.5. Global session layout

vi. Sequential session

For the sequential session, a simple and uncluttered student interface was designed. The navigation space was limited by not providing any additional links on a page. The material was presented in a step–by step way, where the student had to follow the 'Next' link to reach the next page. Figure 4.6 shows a typical sequential session layout. The sequential session applies the "next best" link type of link adaptation (direct guidance) and a linear linking structure is applied to assist sequential progress through the courseware.[3]

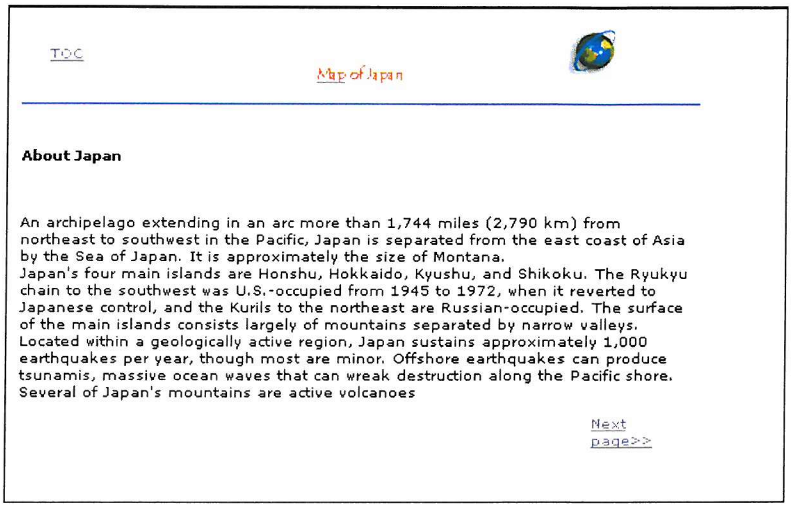

Figure 4.6. Sequential session layout

Linking mechanism applied in the system

Hyperlinks for the global session were created so that they allowed free navigation through the system. The following mechanism was applied throughout the global session, so that it matched the preference for global students:

- Links to more detailed information were provided
- Numerous links were provided within the presented text to allow a more associative, less linear form of browsing
- A table of contents (TOC) representing a hierarchical representation of the lessons was available
- Supplemental links leading to additional information were provided
- The links within text, the sidebar and the TOC were annotated in different colours, indicating which pages have been visited and what additional information is available
- Links to previously read material and the 'next' page had 'descriptions attached to them, providing navigational guidance

For the sequential type of lesson the following linking mechanism was adopted:

- The number of links within the text was small (it was not deemed necessary to confuse sequential students with numerous links)
- No guidance on where the next lesson was heading or description of where the links were leading to, was provided
- A curriculum sequencing technique was applied to browsing

[3] The Appendix C summarises the linking and structural mechanism incorporated within the two learning sessions.

vii. Attitude questionnaire

This questionnaire was used to find the opinion of the students. The questionnaire was designed to assist in the usability study and will be discussed in later chapters.

viii. Management of the student model

In order to keep track of the student actions throughout a browsing session, a student profile needed to be created. Updates to the student profile happened whenever the student completed a particular questionnaire or browsing session. The student's profiles were created at the start of a session, and were saved in a database. The UM consists of the following information:

- The student name and password, age and sex
- Type of information (topic chosen)
- The preferred learning style (obtained from the student questionnaire)
- Knowledge pre and post questionnaire results for both topics
- Attitude questionnaire results

The student unique ID is given to the students when they log onto the system. It helps tracking the students while browsing through the system.

The preferred learning styles: after the students completed the ILS questionnaire, their learning style is assigned to them (sequential learning style SLS or global learning style GLS). A database was set up allowing an administrator to manage this information.

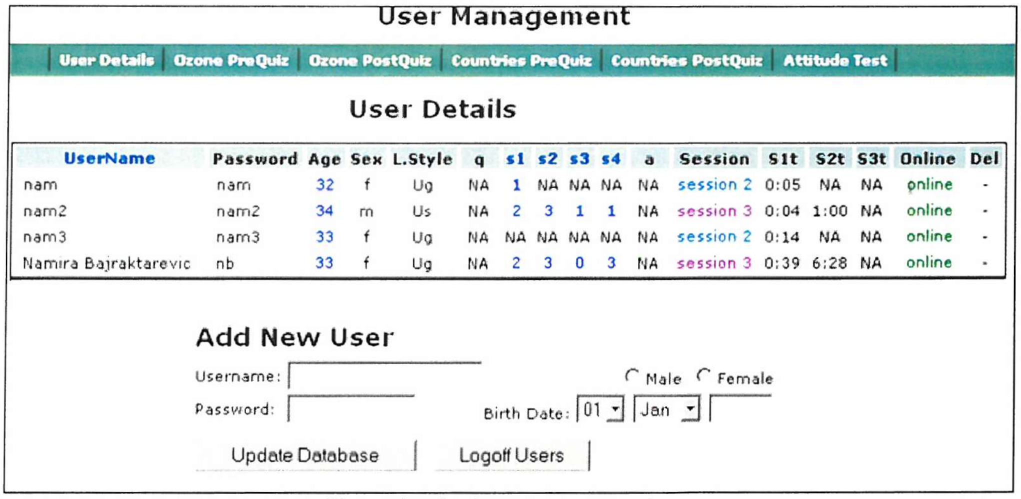

Figure 4.7. Student management logs

Figure 4.7 presents examples of the logs obtained for each student throughout the interaction with the system.

Summary

This chapter has presented a background on the development of a hypermedia application that incorporated learning styles. The learning styles were represented through adaptation of structuring and linking mechanism within two user interface templates. The chapter examined features and properties of each template. The technology used for authoring content and design of the student interface has been described. The chapter also presented the experiment set up for matching and mismatching of the students' learning styles. Finally, this chapter has detailed the tests used to create a user model, essential for obtaining information about the learners and learning style adaptation. The next chapter presents the results of the usability study conducted on LSAS.

Chapter 5. Formative evaluation of LSAS

5.1 Introduction

This chapter describes the usability study of the LSAS (Learning Style Adaptive System) that was conducted during the iterative improvement of the system. The first part of this chapter will describe standard methods for evaluating the usability of adaptive hypermedia systems. The second half of this chapter will present the results of subjective feedback obtained from the usability study.

5.2. Evaluation of usability of educational web-based hypermedia applications

User based evaluation is an important factor in development of any interactive system, especially for complex systems such as AES. HCI evaluation "*...is concerned with gathering data about the usability of a design or product by a specified group of users for a particular activity within a specified environment or work context*" (Preece, 1998). The evaluation of systems can be described as formative and summative evaluation. Draper *et al.* (1996) described formative evaluation as a method that is intended to help improve the design of a system, i.e., as an iterative process. This type of evaluation produces qualitative results. On the other hand, summative evaluation is done after a product is ready. In the "*DxR*" system, Bryce and King (1998) evaluated the software created for medical students, via a means of qualitative and quantitative data gathering methods. They included group observations, focus groups, and a questionnaire to quantify the student responses.

Another of the methods for obtaining subjective feedback and an opinion on the usability of the AES appear to be heuristic evaluation. Heuristic evaluation is a popular and quick way to find problems with the usability of an interface. It concerns the use of a list of good design principles or 'heuristics'. An expert in user interaction design gives a judgement on the particular system, by determining what usability heuristics or guidelines it supports or violates. Heuristic evaluation can be done early on in the design process. Nielsen (undated) listed ten usability heuristics:

The system must make its state visible in a clear and timely manner.
The language of the interface should match that of its students
The language of the interface should be used consistently
The system needs to be forgiving of mistakes (e.g., offer CANCEL buttons)
Where possible, the system should prevent the student making mistakes
Error message must help the student fix up the problem
The system should not make the student have to copy down instructions or information
Information irrelevant to the task at hand should not be shown
Systems should provide shortcuts for expert students
Where HELP information is needed it should be of good quality

Table 5.1. Interface design heuristics (Nielsen, undated)

Squires and Preece (1996) employed heuristic evaluation techniques in an educational framework, where teachers are seen as expert evaluators, required to do heuristic evaluation. Squires proposed a list of heuristics for educational purposes that include questions such as: how appropriate is the content to the curriculum, what form of learner feedback is provided and what the level of learner control is. Squires and Preece (1996) suggested that any technique used by the teachers needs to be relatively quick and easy to use, as heuristic evaluation is designed to address key usability in a cost effective way. The heuristic evaluation process requires teachers to review the student interface, and from their knowledge of how they would present the software to the students, and how the students learn, the teachers judge the suitability of the software for its intended educational purpose.

Quinn *et al.* (1997) suggested modifying usability methods for educational use. He suggested that the evaluators should not only be learners, but educational design experts and content experts. He proposed a list of content heuristics, presented in the Table 5.2.

Heuristics	Explanation
Ensure visibility of system status	The software keeps the user informed about what is going on through appropriate and timely feedback.
Maximise match between the system and the real world	The software speaks the users' language rather than jargon. Information appears in a natural and logical order.
Maximise user control and freedom	Users are able to exit locations and undo mistakes.
Maximise consistency and matches standards	Users do not have to wonder whether different words, situations or actions mean the same thing. Common operating system standards are followed.
Prevent errors	The design provides guidance that reduces the risk of user errors.
Support recognition rather than recall	Objects, actions and options are visible. The user does not have to rely on memory. Information is visible or easily accessed whenever appropriate.
Support flexibility and efficiency of use	The software allows experienced users to use shortcuts and adjust settings to suit.
Use aesthetic and minimalist design	The software provides an appealing overall design and does not display irrelevant or infrequently used information.
Help users recognise, diagnose and recover from errors	Error messages are expressed in plain language, clearly indicate the problem and recommend a solution.
Provide help and documentation	The software provides appropriate online help and documentation, which is easily accessed and related to the users' needs.

Table 5.2. List of Quinn's educational design heuristics (Quinn, 1997)

Quinn *et al.* (1997) also suggests that the evaluators should make two passes through the system noting any comments. Albion (1999) used a combination of evaluation techniques to assess the educational value of a multimedia system. The techniques applied included: heuristic evaluation, observation, interviews and questionnaires. He devised a set of so called content heuristics, which are listed in Table 5.3. Albion (1999) emphasised the need for formative evaluation to be cost-effective.

The results obtained from that study showed both positive and negative comments about the three sets of heuristics applied in the usability study (interface, educational design and content heuristics). Inconsistent comments obtained from evaluators were put down to evaluators' different technical expertise, computer experience and the expectations of the package. However, the combined evaluation techniques proved effective in identifying issues in all three design-aspects. The methods also proved to be a cost-effective evaluation of educational multimedia.

Establishment of context	The photographs, documents and other materials related to the simulated schools create a sense of immersion in a simulated reality.
Relevance to professional practice	The problem scenarios and included tasks are realistic and relevant to the professional practice of teachers.
Representation of professional responses to issues	The sample solutions represent a realistic range of teacher responses to the issues and challenge users to consider alternative approaches.
Relevance of reference materials	The reference materials included in the package are relevant to the problem scenarios and are at a level appropriate to the users.
Presentation of video resources	The video clips of teacher interviews and class activities are relevant and readily accessible to the user.
Assistance is supportive rather than prescriptive	The contextual help supports the user in locating relevant resources and dealing with the scenarios without restricting the scope of individual responses.
Materials are engaging	The presentation style and content of the software encourages a user to continue working through the scenarios.
Presentation of resources	The software presents useful resources for teacher professional development in an interesting and accessible manner.
Overall effectiveness of materials	The materials are likely to be effective in increasing teachers' confidence and capacity for integrating information technology into teaching and learning.

Table 5.3. Content Heuristics (Albion, 1999)

Wills *et al.* (2000) conducted a very thorough evaluation of a combination of FIRM (the industrial hypermedia system). Usability techniques adopted in this system included the systematic user evaluation (SUE), (Garzotto *et al.,* 1997), structured expert reviews, interviews and attitude questionnaire. The attitude questionnaire was designed to measure different dimensions of the Software Usability Measurement Inventory (SUMI) (Kirakowski, 1993, Hirst *et al.* 1995). To employ structured expert review, the experts focused on general graphical user interface (GUI) aspects by using Nielsen's (1994) list of heuristics. Through the use of interviews, Wills *et al.* (2001) ensured that unattractive and unusable features of the system were removed at an early stage of system design. Attitude questionnaires were gathered over a period of time at the start and also at the end of the system trial period (6 months in this case).

5.3. Evaluation of usability of adaptive hypermedia applications

In the past few years, a lot of research work was focusing on the evaluation of educational adaptive hypermedia systems, especially on underlying information structures and navigational support. Assessing users' satisfaction of AES has actually become the norm. The following section describes the usability evaluation criteria and techniques used in some AES created in the past few years.

In the system PUSH (Höök, 1996b) the author asked the following questions in order to ascertain a student's point of view and attitude.

- Various aspects of the user interface of the system
- Student's preferences for either adaptive or non adaptive version
- Whether the system adapts to their needs appropriately
- Whether they liked the user interface

The number of evaluators in usability studies is usually small, in this case there were 9 evaluators. The type of evaluators in this system were students.

In the system called HyLITE+ (Bontcheva, 2002), in order to examine the subjective satisfaction, the author asked the following feedback:

- User's impressions of both systems,
- Ways of improving the generated hypertext
- If they encountered problems while interacting with it
- System response time for both versions
- If they find the adaptive version intuitive to use
- If they find the adaptive version confusing to use
- Students were asked what improvements to use, such as would it make any difference if the students could control the adaptive behaviour

The number of evaluators in this system was small again, in this case, eight participants. The evaluators were postgraduate students and research staff at he Computer Science department.

In the '*mspace*'; system (schraefel *et al.*, 2003) the participants were asked about their preferences between two adaptive techniques (stretchtext vs. zooming) offered in the system, used for a particular set of tasks and the overall difference between the two adaptive techniques. The number of students performing the evaluation was small again, in this case, twelve students.

In '*Percy*' (Paris *et al.,* 2003) usability evaluation, the authors compared the 'Percy' system with a search engine and asked the students (evaluators) for feedback regarding the following:

- The interactive experience-the quality of the tailored content
- Attitude towards the presentation format
- Further interaction influenced by a student's belief or attitude
- Adaptive system providing a better explanation, attracting my attention more
- The overall preference between Percy and another search engine

In the system called *Hezinet* (Arrubarrena *et.al.,* 2002), in order to measure the affective impact of *Hezinet,* the authors used an open-ended questionnaire. This questionnaire posed the questions regarding the elements of the system that were more helpful and the elements of the system, which were more pleasant to use.

In '*Sady*' (Hothi and Hall, 1998), an attitude questionnaire was used as the main usability method. In addition to using questionnaires, the authors used interviews and a focus group to obtain subjective satisfaction on the usability of the system. The number of evaluators was eight, which included a tutor who was involved in a focus group. The interviews were held to gain a deeper insight into what aspects of the GUI the tutors felt needed to be changed. Questions regarding the freedom given to students by the system, the ability to maintain masses of different types of data and the functionality, were presented to the students. The evaluators could also send comments on the features of the system (search algorithm, the linking features, openness of the system for learning goals, 'getting lost' phenomena). The focus group included students as the main evaluators, where they were encouraged to openly discuss their views on the application. They were asked if they enjoyed using the application and whether they found it useful. The questionnaire posed questions about the following:

- If they needed much help using the system
- If the system provided too much navigational freedom
- If the students wanted to ask the system for assistance
- If they wanted the system to offer hints and guidance
- If the error messages they received were relevant to any problems they encountered
- If undoing and redoing operations was easy

This appears to be the most comprehensive system to date that incorporated three different usability methods.

Murray *et al.* (2001) in the system 'Metalinks' conducted a usability evaluation where the authors used a 59-item questionnaire. The usability study was combined with a focus group for general discussion of the experience. The questionnaire asked questions relating to overall satisfaction, navigational issues, the exploratory behaviour, the importance, and ease of use of the navigational features. The authors' primary goal was to address the learner's subjective experience; in terms of usabilty and the satisfaction of goals therefore such a lengthy questionnaire was posed.

'Easymath' (Virvouu and Tsiriga, 2000) was an intelligent tutoring system where the usability was tested. The evaluators were teachers and students (ten schoolteachers and 240 students were involved). The teachers were asked to evaluate the overall performance of the system and express their opinion on the usability of such a system. For teachers a set of heuristics (guidelines) was developed. Introduced by Squires and Preece (1996), the set of guidelines are an adaptation of the guidelines developed by Nielsen (1994), as they are based on a constructivist criterion of learning. The teachers conducted 'predictive evaluation'. This type of evaluation is usually conducted when making decisions on purchasing the software. The questions for students included the following:

- Were the features of the system comprehensible and consistent
- Were the features convenient
- Have they enhanced attention
- How were errors handled
- Was the system efficient
- Have the features been useful
- Was it easy to become familiar with the system
- Was it tricky to use the system

Student-based evaluation is an essential component of developing any adaptive hypermedia application. The evaluation methods found in previous literature revealed that most educational systems used a combination of evaluation techniques such as questionnaires (Bryce *et al.*, 1998, Brusilovsky and Eklund,

1994) and heuristic evaluation (Nielsen, 1993, Squires and Preece, 1996), where experts evaluate how the interface complies with a list of heuristics or usability criteria. From the review of usability studies conducted in the adaptive systems, it is apparent that the most popular method of testing usability is by setting up a questionnaire to test the students' satisfaction. Very few systems depart from that and rely on teachers or UI experts (Murray *et al.* 2001, Virvouu and Tsiriga, 2000). A combination of all three techniques is considered to be the most structured and through method for measuring users' satisfaction of a particular system.

5.4. Methods used for usability testing of LSAS

A usability study was undertaken to ensure the ease and user-friendliness of the user interface in LSAS. It examined the efficiency of the system, such as ease of accessing the site, ease of navigation, reliability of the system (i.e., the students do not experience problems or delays accessing material), absence of missing links or other link related problems. This section presents the results of the evaluation for each method of evaluation applied. The results are split into three parts: results obtained from the students, results obtained from the expert reviews and results obtained from the logs. Nielsen (1994) found that 75% of usability problems are found with the first three to five evaluators (See Fig. 5.1). He suggested that the participation of more evaluators would result in only marginal improvements in the rate of detection.

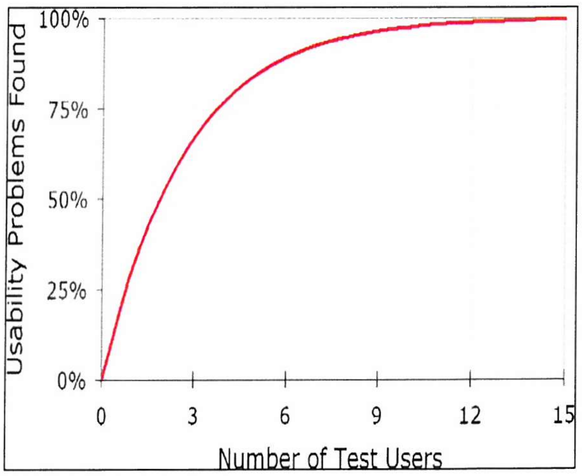

Figure 5.1. Jakob Nielsen's Alertbox (Source: http://www.useit.com/jakob/)

In order to assess students' experience of using the WWW, experience in performing various actions on computer, a length of time spent on a computer, use of different environments and experience in using the search engine, a demographic background questionnaire was used. See Appendix B for the full list of questions contained in this questionnaire and the answers obtained from it. For the usability study two sets of trials were undertaken. The first set was organised at Brighton College, and consisted of 15 students, two teachers and a software tester. The students were observed by the teachers and were informed how to start the system. However, this set of students did not manage to complete the usability trail. The main reasons were the following:

- The content proved to be too difficult for the chosen age group
- The students had motivational constraints
- The time taken to browse the first half of the course proved to be too long
- There was too much material to go though at one sitting
- The students could not leave the system and come back to it

These issues had to be addressed immediately, before proceeding as the system proved to be in unusable state in its early form. The system was then modified by taking into account the issues. Once these serious usability issues were addressed, a second set of trials was undertaken. All the tests were performed individually and the students were not observed during the study. However, the students were encouraged to report any issues they come across via e-mail. The main evaluation techniques employed in LSAS were heuristic evaluation conducted by experts and an attitude questionnaire. These techniques will be presented and the process of evaluation discussed in terms of what is questioned and what judgements were made.

5.4.1. Usability study-structured expert reviews

As part of the usability trails four independent evaluators reviewed the system. The team comprised people with different skills: teachers, student interface design expert, a learning style enthusiast and software testers. The age of the reviewers were between 25-35 yrs old. All the experts use computers and the Web on a daily basis during the course of their work. In order to prepare for an evaluation session, the evaluators were given a list of heuristics. These heuristics were based on heuristic principles devised by Nielsen (1994). The questions in the heuristics focused on technical, as well as educational issues. They included the usability of the system, software design, learning style representational features, content and user interface issues. The experts were encouraged to report any strengths and weaknesses of the system, as well as any errors they have encountered. The evaluation sessions lasted three hours in total. The evaluators were instructed to browse through the WWW prototype (no specific scenarios were presented, though two sample usage patterns were emphasised), to identifying potential usability problems.

Each evaluator performed the test individually and each performed a slightly different type of evaluation. One expert was asked to perform a walkthrough, another to review educational content and two evaluators were asked to perform a predictive evaluation. In all, the experts looked critically at the system, rationalized the good and bad aspects of the design choice and formulated potential improvements. The issues they came across were divided into:

- Serious problems (such as system stops responding, inability to log in)
- Intermediate problems (such as broken links that may prevent the students from being able to continue browsing)
- Trivial problems (such as inconsistencies in the layout, spelling mistakes)

Appendix B contains a complete listing of common themes and recommendations made by expert reviewers.

5.4.2. Usability study - attitude questionnaire

In order to obtain a subjective feedback opinion of the student interface, a 20-question measure was developed. Questions 1-12 focused on the contribution that the web site made to student learning and possible predictor variables such as pace, enjoyment and access. Questions were also directed towards investigating which features the students found most helpful in the learning the material. This questionnaire was presented to the students after they completed interacting with both versions of the system, *i.e.,* at the end of the usability trial.

A small number of students (five GCSE students) completed an attitude questionnaire. This is not a large enough number of students to draw any conclusions about their interaction with the system. Nevertheless, a synopsis of their feedback follows. The students were asked about the presentation, learning style representation elements, control of the system, and the overall impressions of the system.

Presentation and guidance results

In this part of the questionnaire the students were asked what they thought of the presentation (layout, summary, overview, additional information) and guidance features (search, link annotation, number of links) of the system. Most of the students had a positive attitude towards the system. Half of them agreed that the colours chosen for links were appropriate and the second half of the students strongly agreed on that point.

Exploration and navigational freedom

In this part of the questionnaire the student opinions about the exploratory-based type of learning features (structural mechanism, reference information) provided by the system and the navigational support and freedom (access to the table of contents, disorientation, freedom of movement) features were gathered. The students were divided in their opinion between feeling disoriented whilst interacting with the system: half of them felt disoriented at some point, some of them did not. Similarly, their opinion varied on the structure of material presented. Half of the students thought that the structure was not appropriate. From this it is not obvious which session they were referring to (global or sequential), as the attitude questionnaire did not divide questions into these two areas. Many students strongly agreed that a table of contents that provided a central point of navigation through the system was useful.

Learning style representation opinions

In this section of the attitude questionnaire, students were asked about their point of view on some of the elements of the learning style representation (the volume of text, the number of links within pages, and the help features provided). More than half of the students agreed that the layout was clear and that the guidance level provided was appropriate. They agreed that particular elements (overview, summary, additional references) of the learning style representation were helpful.

They were asked about the amount of text shown and the number of links introduced in each lesson. Sequential students have found that the number of links in their mismatched session (global) session was too large. This was the expected result. They also indicated that that there was too much text within their mismatched presentation (global interface). These results are in agreement with the theoretical assumptions about what kind of learning style representation these students prefer. On the other hand, some Global students found that there was too much text on each page for their matched session. The teachers, backing up this feedback, added this comment later.

Overall impressions of the system

The students were divided in their opinion about whether it was easy to become familiar with the system. This indicates that some improvements need to be made regarding the initial instructions, such as how to use system. Finally, almost all agreed that learning objectives were clear and that system was easy to use. Similarly most students reported that the assessment methods were clear.

Summary

The main issue with the usability trial was finding enough students to perform the study, as the timing for the evaluation in terms of the typical school year was not ideal. However, even with five participants, valuable data was gathered. The results from the usability trial showed that all three methods found different usability problems. The results were gathered by different methods, by different groups of people, focusing on different tasks and system aspects.

The usability study showed that, in order to satisfy educational requirements, the expert reviewers expected learning style representation to be done in more depth, specifically through the form and courseware content, rather than just its layout linking and navigational structure. Expert evaluations proved to be very useful in the usability study. However, there are limitations such as that none of the experts found problems related to the system reliability and the usage context. However, they found a lot of problems concerning interface, layout and information organisation, which might not have been noticed in the student tests. Their recommendations and the proposed changes improved system usability. The results showed that both methods found different problems in different cases.

Potentially, it would be useful if teachers (experts) performed predictive evaluation first before the students.

On the other hand, the points that the students raised were the following:
A few of students had a reliability issue, where they were logged out of the system unintentionally. This caused confusion, but the problem could not be reproduced. The issue might have been associated with web hosting site maintenance. Secondly, the content level appeared to be difficult, above GCSE student comprehension levels. The topics chosen for the study were not found by the students to be particularly entertaining or interesting and the students found it difficult to concentrate on the task or its completion. All of the students agreed that time taken to go through the system should be reduced. They also agreed in the majority that the objectives should be clarified more and that the content should be reduced.

Formative evaluations are vital to the development of novel systems and help solving initial problems and ironing out any interface design issues of a system. It is apparent that at least one of the benefits of utilizing a mixed method approach to evaluation is the greater sophistication of measurement questions generated. In general, the results have emphasised the weak points of the system and brought out the good points. It did mean that the system needed big changes in terms of clarifying the objectives and reduction of content. Some cosmetic changes were necessary too.

The next chapter describes the empirical analysis of the LSAS and the main hypotheses postulated in the evaluation. The analysis applied to the data gathered during the experiment and the results obtained are presented.

Chapter 6. Empirical evaluation of LSAS: quantitative results analysis and interpretation

6.1. Introduction

This chapter describes the results of an experimental study that was conducted in order to test the adaptive features of LSAS (Learning Style Adaptive System). The first part will review the existing methods used in the evaluation of AES. The second half of the chapter will presents the results obtained as part of the study and discuss the implications of the results for the design of adaptive courseware. The following section describes the methods employed and evaluation criteria for the empirical evaluation criteria employed in a number of AES.

6.2. Empirical evaluation of adaptive systems

Empirical evaluations of adaptive hypermedia systems are still very rare. Evaluation of adaptive systems is "concerned with system performance and the system's decision making capabilities" (Gilbert *et al.*, 2001). Evaluation of something as complex as AES is not an easy task. From the literature review it became apparent that the most recently conducted empirical evaluations fall into these categories:

1. Testing what effect the adaptivity (Adaptive Navigation Support (ANS) and/or Adaptive Presentation (AP)) has on learning performance and the user's satisfaction (the "with and without adaptivity" approach)
2. Testing the effect of user modelling
3. Layering the levels of adaptivity
4. Testing the contribution of the effect on one adaptive technique over another

6.2.1. Testing the effect of adaptivity on learning performance and user's satisfaction (the "with and without adaptivity" approach)

The predominant method of empirical evaluation appears to be a comparison of a non-adaptive with an adaptive version of the system (Kaplan *et al.,* (1993), Boyle and Encarnacion, (1994), Höök, (1996b), Bontcheva, (2002) and Woods and Warren, (1996)) amongst others.

Höök (1996a) suggests that the interface design is often inextricably linked to the adaptive component in an adaptive system. She asserts that

> *"it is of crucial importance to be able to distinguish the adaptive features of the system from the general usability of the designed tool. This is probably why most studies of adaptive systems are comparisons of the system with and without adaptivity".*

Höök points out that the problem with such a process is that the non-adaptive system may not have been designed 'optimally' for the task, i.e., it should be the case since adaptivity should preferably be an inherent part of a system. Höök (1996b) in the system called PUSH evaluated how much adaptivity reduced the number of actions needed to perform a particular task, in this case to retrieve information. The PUSH system can either infer student information-seeking tasks from their actions or the users can set the task themselves. Based on the information-seeking task, the system chooses what to show and what to hide in a page using a stretchtext technique with the purpose of avoiding information overload. Höök also studied the preferences students had between adaptive and non-adaptive systems.

Brusilovsky *et al.* (1998b) conducted an experiment that was designed to assess the impact that the student-model based-link annotation has on learning performance. They used audit trials and questionnaires as part of their evaluation. Their results indicated that the adaptation they employed is advantageous to learners who choose to accept the navigational advice.

In many studies (for example Boyle and Encarnacion, 1994; Brusilovsky and Pesin, 1995) the main evaluation criterion of adaptation is in task completion time. Kaplan *et al.*, (1993) measured how many nodes the students visited. Brusilovsky and Pesin

(1995) conducted an experiment with the ISIS adaptive tutor with twenty-six students. They tested the following: the number of repetitions of previously studied concepts, the number of transitions from concept to concept; transitions from index to concept and the overall number of navigation steps. They found that the number of movements were significantly fewer for students with the adaptive version of ISIS tutor, and concluded that adaptive annotation made learners more purposeful, completing the work with fewer navigation steps.

A more recent paper by Bontcheva (2002) shows that the author used the 'predictive evaluation technique', which involves a small number of the users following a set of scenarios. Each scenario consisted of a few hypertext pages, which presented information in alternative ways. Bontcheva (2002) conducted a preliminary evaluation of the *HYLITE+* system (that tests the student's reading behaviour such as readers vs. skimmers), by using two versions of the system: a baseline one and the adaptive one. The non-adaptive version looked the same with the adaptive elements switched off. The evaluation consisted of questionnaires, student interaction logs and semi-structured interviews. The participants performed the first set of tasks with the non-adaptive system, and then swapped systems for the second set of tasks. The tasks varied from browsing to problem solving to information locating. The student logs were used to extract information such as average time per task, number of pages visited, percentage of correctly answered pages, student preferences, and number of links followed among others.

Hothi and Hall (1998) evaluated the *SaD* (Static and Dynamic) system by using various techniques, such as comparing adapted presentation and adapted navigation with a non-adapted control hypermedia application. The experiment involved the implementation of three 'Archaeology Dating Technique' applications, one of which adapted the presentation of links (Application A), another of which adapted the document content (adapted presentation) (Application B) and one as a control hypermedia application without any form of adaptation (Application C). The results of the experiment were obtained via questionnaires, session logs data and observation. The experiment was set up in such a way that the participants were given pre-test questionnaires and depending on their subject and system knowledge, they were allocated one out of four stereotypical static student models.

Woods and Warren (1996) evaluated how adaptive the *LOOP tutor* (tutor for learning loop constructions in Pascal) improved student learning. Their methods included tests of student performance before, during and after using the application, questionnaires about their impressions of the system and its interface design, and automatic activity logging. The students were allocated at random to a non adaptive (menu driven) or an adaptive application. 50 students took part in the experiment. The results indicated no significant difference between navigation methods nor a significant difference for learning performance between the two versions of the application. The results have shown that the time spent on the adaptive version was slightly shorter than the time spent on the non adaptive version.

Guven-Smith (1999) analysed individual navigational patterns in non-adaptive and adaptive versions using a system called *MLtutor*. 30 students took part using four different versions of the system in the field of environmental science. User interaction and results were gathered using a student feedback questionnaire, answer sheets and log files. The log files provided information such as visited page name, page access time, suggestions discarded by the students and website transitions. The logs also provided information regarding the usage of three types of links present in the system (built-in links, suggestion list and a bookmark list). Evaluation criteria for this system were the total task completion time, total usage of links, total usage of suggestion links and total usage of bookmarks.

6.2.2. User modelling (UM) evaluation

This is another method used in the evaluation of AES. Chin (2001) reviewed empirical evaluations of user models and user adapted systems. He investigated which users are helped and which ones are affected by the adaptivity. Chin (2001) points out the problems in the empirical evaluation of UM. He suggested a reporting standard that included the following:

- The number and size of participants
- The participants' background
- The analysis methods
- The post-hoc probabilities

- The raw data
- The effect size (treatment magnitude)
- The power (inverse sensitivity)

6.2.3. The layered approach to empirical evaluation of AES

This is a relatively new approach to evaluation of AES. The layered approach to evaluation implies that a successful evaluation of a previous layer is a prerequisite for the subsequent layers. Karagiannidis *et al.* (2001) introduced the concept of 'layered evaluation' for adaptive applications, where the success of adaptation is addressed at two layers: interaction assessment and adaptive decision-making.

Weibelzahl (2001) explored the methodology for this type of empirical evaluation and suggested that evaluation of adaptive elements should consist of the following layers:

- Evaluation of reliability and external validity of input data acquisition
- Evaluation of the interface mechanism and accuracy of user properties
- Appropriateness of adaptation decisions
- Change of system behaviour when the system adapts
- Change of quality of total interaction

Brusilovsky, Karagiannidis and Sampson (2001) demonstrated the benefits of using a layered approach to adaptive link annotation in the *Interbook* system and suggested the use of such evaluation in future evaluations of adaptive systems. They decomposed evaluation into evaluation of interaction assessment and adaptation algorithm assessment. Their study brought no significant results in learning for the students who used the system with user-model based link annotation, i.e., the adaptive navigation support techniques did not influence students' performance.

6.2.4. The comparison of two adaptive techniques

This method is one of the latest suggestions for evaluating AES. It was introduced by Tsandilas and schraefel (*mspace*, 2003). This approach evaluated the effect of one adaptive technique (zooming) over another (stretchtext). The participants in this experiment were given two types of tasks: gathering and locating information by using two canned text techniques (zooming and stretchtext). The authors were looking for the efficiency and the usefulness of their technique (fisheye view) compared to the stretchtext. They argued that zooming technique could balance a time trade off between information overload and lack of context. The number of participants in the experimented was six post-graduate students. They were presented with a single variation of user interface and expected to perform 12 different tasks. Six of the tasks were designed to measure the ability of each technique to help users locate information and another six tasks were created to access the effect of the technique in helping the students to gather information. The only independent variable in the experiment was the adaptation technique. The dependent variables were the number of correct answers and the number of double clicks on paragraphs. The authors measured the length of time the participants spent to complete the tasks. The authors have emphasised the fact that the length of time taken by the students to complete the tasks should not be the main evaluation criteria. Both sets of students performed equally well in terms of the time it took to complete the tasks. However, the authors argue that the first adaptive technique (stretchtext) is more difficult to author.

6.3. Evaluation criteria used in adaptive educational systems

From the literature review it appears that the following criteria is used in the majority of AES:

- Time spent on the adaptive version vs. non adaptive version of the application
- Learning performance increase between two versions of the application
- Number of hyperlinks visited in both versions of the application
- Number of repeated links visited in both versions of the application
- Use of navigation support tools in both versions of the application
- Previous knowledge (for example novice versus expert user)

6.3.1. Time spent on the adaptive version versus non adaptive version

The 'time-spent' criterion was used in the following adaptive systems: *Metadoc* (Boyle and Encarnation, 1994), *PUSH* (Höök, 1996b), *mspace* (Tsandilas and schraefel, (2003)) and *Hylite+* (Bontcheva, (2002)), among others.

In the study conducted by Boyle and Encarnacion (1994), *Metadoc*, the main evaluation criterion of adaptation is in task completion time. The hypothesis was that *Metadoc* users would spend less time locating information compared to hypertext and stretchtext users. The results obtained partially supported their hypothesis, as the users who used *Metadoc* spent less time than hypertext users.

In *PUSH* (Höök, 1996b) there was a weak tendency that the adaptive system reduced the search time. Bontcheva (2002) tested average time per task, number of pages visited, percent of correctly answered pages, the student preferences, and the number of links followed as evaluation criteria in *HYLITE+*. The mean time per task (browsing and searching tasks) results showed that the students who used the non–adaptive version of the application took longer on average.

Time spent 'learning' was measured in *ISIS TUTOR* (Brusilovsky and Pesin, 1994), where the results indicated that the adaptive presentation technique reduced the time spent during learning and can improve comprehension.

6.3.2. Evaluation of learning performance increase

Few systems have evaluated the benefits of applying adaptivity in hypermedia i.e., measured learning performance increase. In Eklund *et al.* (*Interbook*, 1997) the student test scores were used as a criterion to measure the effects of adaptation. The results obtained, however, did not indicate significant statistical difference between the test scores obtained for the adaptive and nonadaptive versions of the system.

Specht and Kobsa (1999) also evaluated student performance. They used a demographic questionnaire and several knowledge tests. The tests consisted of 12 questions about central concepts. The main variables in the test were the time to read all hypermedia nodes and the number of correctly answered questions. The results showed that in all tests there was a significant improvement of correctly answered questions from the pre-test to post-test.

In *Hylite+* (Bontcheva, 2002) an average user score per information location task was computed. The results indicate that the students had higher task success rates with the adaptive version of the system.

Boyle and Encarnacion (*Metadoc*, 1994) measured the difference between reading comprehension, whereby the students who used this system received better reading performance compared to the use of stretchtext. Their system *MetaDoc* uses the "stretchtext" technique, whereby the students learn in a self-directed, explorative manner whilst browsing. In the 'hypermode', the student is guided through the course material in a personalised way, where the important points are emphasized, and the useful material illustrated. No significant results were found.

In another study, Weber and Specht (*ELM ART II,* 1997) measured the performance results of students who used the system with and without adaptive navigation support. The techniques they used were adaptive annotation and adaptive sequencing. The results obtained from this study indicated that the adaptive sequencing technique (the use of the 'next' button) helped only novice users with no previous experience of programming. Additionally, the results suggested that the adaptive annotation technique did not assist novice users at all.

6.3.3. Total number of hyperlinks visited in both versions of the application

This criterion was used in *Hylite+* (Bontcheva, 2002), *Isis Tutor* (Brusilovsky and Pesin, 1995), and *MLTutor* (Guven-Smith, 1999). The expectation is that in most of these systems, the total number of steps will be reduced with the adaptive application. Kaplan *et al.* (1993) and Weber and Specht (1997) measured how many nodes the students visited too. The authors of *Isis Tutor* (Brusilovsky and Pesin, 1995) measured the number of links visited and revisited. The results indicated that the number of nodes visited was reduced by the adaptive annotation technique. Similarly in *PUSH* (Höök, 1996b), it was found that the adaptive system reduced the number of actions within pages as compared to the number of actions between pages. Bontcheva (2002) tested the number of pages visited per task and the results indicated that, on average, the students visited more pages per task in the non-adaptive version of the application.

6.3.4. Number of repeated links visited in both versions of application

This criterion was used in *mspace* (2003), *ISIS Tutor* (1995) and *Hylite+(*Bontcheva, 2002). In the review of these evaluations, there is no clear explanation as to why these links were revisited and why this is an important factor in the evaluation.

6.3.5. Use of navigation support tools in both versions of the application

This technique was used in *JointZone* (Ng, 2001) where the use of an adaptive personalised topic map as opposed to a table of contents was monitored. The time taken to complete the tasks using the tools, the learning performance and the average number of steps performed, by using the two navigational tools, were measured.

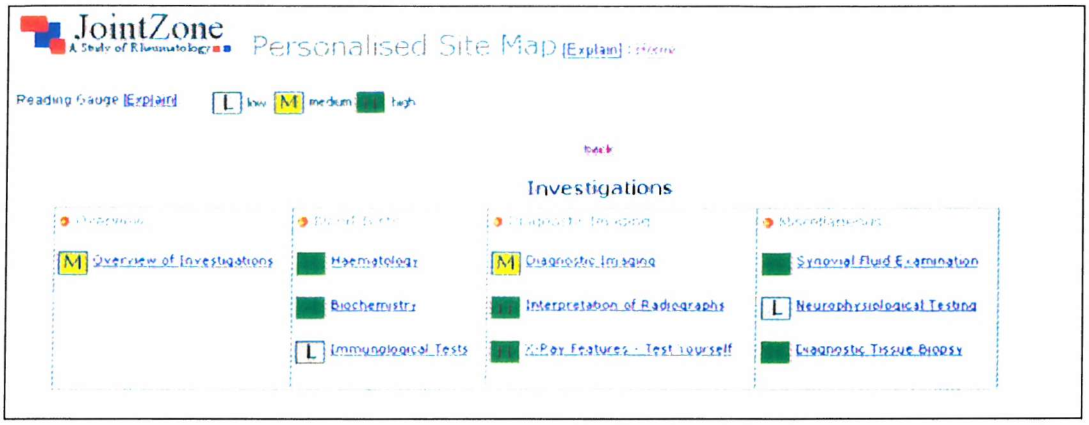

Figure 6.1. Personalised topic map navigational tool in 'JointZone', Ng (2001)

All results were significant in favour of using the adaptive topic map tool. In *MLTutor* (Guven-Smith, 2001), the use of the 'list of suggested favourites' was monitored. Results indicate that on average the preferred navigation method was to use non-adaptive (inbuilt) links in the system compared to the suggested list (adaptive) links. Similarly, Höök (1997a) monitored the choice of navigational tools (graphics, hotwords and menus) for different tasks. The results show that the number of requests for the tools on average is not much different between the two versions of the system. Another example is *Interbook* (Brusilovsky and Euklund, 1999), whose monitoring-log results indicated that navigation tools (link annotation in this case) were not used by some users. In *Hylite+,* (Bontcheva, 2002) the use of navigation tools, such as links, navigation browser buttons and topic lists were measured. The results indicated that such tools were used more in the non-adaptive versions of the system.

6.3.6. Previous knowledge as an evaluation criterion

Previous knowledge (e.g., novice *versus* expert user) is another criterion used in the evaluation of AES. This criterion was used in *SaD* (Hothi, 1998), where depending on their previous knowledge, the users were allocated different user models. In *MetaDoc* (Boyle and Encarnacion, 1994) evaluation, the adaptation applied had different effects on experienced and novice users. In *Hylite+,* (Bontcheva, 2002), novice users exhibited a larger difference between task scores with the two versions of the system, while a 'medium ' level group of users performed equally well on both versions of the system. In *AST* (Specht and Kobsa, 1999) the results showed that users with different previous knowledge were affected differently with the use of adaptation. Experienced users benefit more in an adaptive environment if they had full access to all information. They benefited from adaptive annotation of links (non-restrictive adaptation). Novice users benefited more with adaptive guidance and adaptation to their current knowledge. Neither novice nor experienced users learnt significantly more. In *NetCoach*, Weber and Weibelzahl (2002) conducted an evaluation study in which they have shown that the adaptation to users' prior knowledge by the 'HTML Tutor' application reduces the task competition time and retains learning gain.

Summary

In summary, it appears that the majority of recent adaptive hypermedia systems that have been evaluated adopt a combination of techniques. The chief method for evaluating adaptive hypermedia seems to be to compare non-adaptive version of the system with the adaptive version. In addition, they conducted a student attitude test to gain information regarding student preference and satisfaction with the system. In the following section, the evaluation approach used in LSAS is described in detail.

6.4. Overview of the LSAS experimental study set up

The evaluation of the system described in this study has been conducted using the comparison method of "adaptive" versus "non-adaptive version" of the system, measuring the learning performance difference between them.

Sample

The study involved a sample of twenty-two GCSE students. They browsed through two different versions of web-based hypertext courseware; one version (the first) matched their preferred learning style and the other did not. The learning styles incorporated into the hypermedia courseware were global and sequential learning styles (Felder, 1988). Two different user interface templates representing two learning styles were created. Pages designed to support students with the global learning style comprised guidance and navigation scaffolding elements such as a table of contents, summary and link descriptions. (See Appendix C for a detailed layout of the pages). Pages designed for sequential students contained small chunks of information, text-only pages with 'forward' and 'back' buttons. In performing browsing, students used a standard browser to navigate hypertext pages. Both sets of courseware were part of the GCSE syllabus. One of the subjects was developed and adapted from a GCSE geography book (Pallister *et al.* 2001) and the material for the second course was a mixture of web resources. Twenty–one out of twenty two students completed the experiment.

Before the start of experiment the students learning styles were evaluated using a web-based, self-administering Felder-Soloman ILS[1] (Soloman *et al.* 1992), which assessed four learning style dimensions. The questionnaire is freely available, and it consists of 44 questions, with the results of each dimension of learning styles spread over the scale of 1 to 11. Attention in this study was focused on the bi-polar nature of the ILS scales, global-sequential dimension. Felder and Soloman (Soloman *et al.* 1992) described the interpretation of ILS-results in the following manner:

- "If your score on a scale is 1-3, you are fairly **well 'balanced'** on the two dimensions on that scale.
- If your score on a scale is 5-7, you have a **moderate preference** for one dimension of the scale and will learn more easily in a teaching environment which favours that dimension.
- If your score on a scale is **9-11**, you have **a very 'strong' preference** for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference."

Methodology

At the start of the study, the students read a short explanation concerning use of the system. They then logged onto the system and their learning styles were recorded. The students then answered ten questions regarding the first learning session and then proceeded to browse and study the material. Having completed that, the students were

[1] (Index of learning styles)

presented with the recall-type post-test. The questions were fill-in-the-gaps questions. The questions were declarative knowledge questions, and they tested recalling of facts, terms and concepts, as suggested in Bloom's taxonomy (1956). The taxonomy provides a useful structure in which to categorise test questions that commonly occur in educational settings. It also divides the way people learn and includes three domains: the cognitive, psychometric and affective. The cognitive domain emphasises intellectual outcomes. The main categories of cognitive domain include the following: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). The learning outcomes in this study were tested on the knowledge and synthesis of information. Knowledge is defined as exhibiting previously learned information by recalling facts, terms, basic concepts and answers.

In the second part of the study, the students logged in again, and answered 10 questions about the second set of courseware. They proceeded to browse and study material (which was presented in a different manner, using the presentation format that did not match and scaffold their learning style). Upon completion of the 2nd browsing session the students answered the post-test. The two main dependent variables in this study were the achievement scores obtained in the two post–tests and the session-browsing times. The learning style scale was taken into account and the students with more extreme results on the ILS scale (5-11) were expected to obtain higher scores after they had browsed their matched session. For this study significance testing or hypothesis testing was used, which is "a systematic approach to assessing whether, in light of sample evidence, an assertion about one or more populations should be accepted or rejected" (Morse, 1993).

The hypotheses and the results obtained in the study were divided into three groups: Analysis was performed for all the students participating in the study and then the results were split into three groups, interpreting each group on Felder's scale separately *'All students'*, *'Moderate students'* and *'Balanced students'*.

6.4.1 Hypotheses postulated in the study- valid for all students in the study

In significance testing, two hypotheses need to be formulated: the null hypothesis $\boldsymbol{H_0}$ and the alternative one $\boldsymbol{H_1}$. The null hypothesis is an assertion about a population and is presumed to be true until rejected. The alternative hypothesis H_A contradicts the null hypothesis. The hypotheses postulated for this study were the following:

- *Null hypothesis for the test scores:*

1.

H_0: *Post-test-score means for matched*[2] *and mismatched sessions are not significantly different*

H_A: *Post-test-score means for a matched session are significantly higher than for a mismatched session*

- *Null hypothesis for the browsing times:*

2.

H_0: *Browsing times for matched and mismatched sessions are not significantly different*

H_A: *Browsing time for a matched session is significantly shorter than for a mismatched session*

- *Null hypothesis for the test scores and browsing times for all students:*

3.

H_0: *Students will NOT achieve significantly higher score differences if browsing a matched session in a shorter length of time*

H_A: *Students will achieve significantly higher score difference if browsing a matched session in a shorter length of time*

6.5. Data collection and analysis

To compare performance among the students, the times for both browsing tasks and the answers to all four sets of questions were logged. The results were analysed to determine whether significant differences between score means occurred for different session types. Twenty-one out of twenty two students completed the experiment. Nine of them were sequential students and twelve were global students, so there was a fairly even distribution of learning styles. Nine (23%) students were female and twelve (76%)

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[2] A '*matched*' session refers to the one where the hypermedia material is adapted so that it matches a student's learning style and a '*mismatched*' session is the session where the hypermedia material presentation and navigation do not match the student's learning style.

were male students. Figure 6.2 depicts the division in learning styles preference on Felder Silverman's scale. The majority of students (12) fell into the 'balanced learning styles' category, eight of them were students with moderate preferences and only one student had a very strong learning style preference.

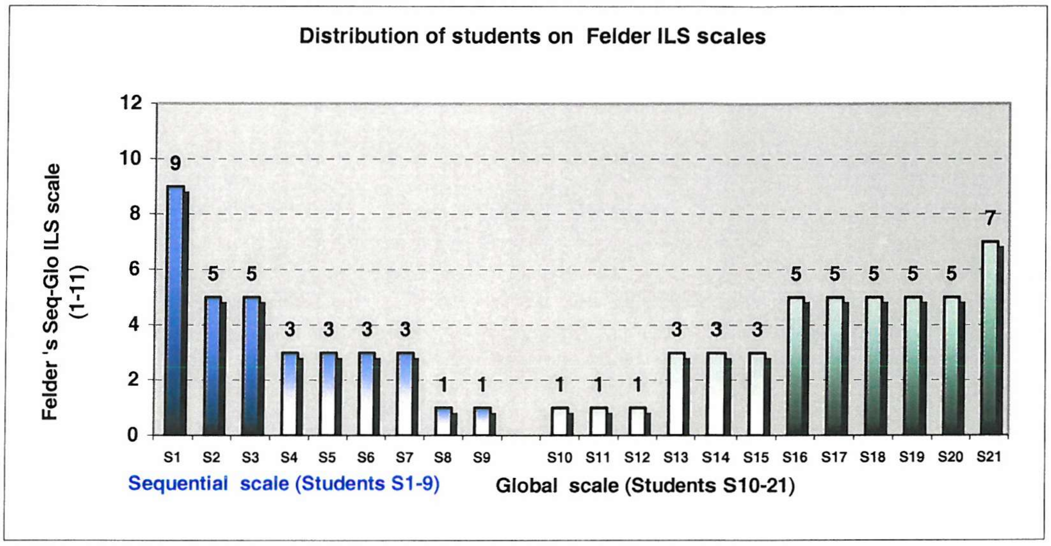

Figure 6.2. Distribution of students on Felder -Solomon global and sequential scale of learning styles

The study was conducted on Windows™ 2000 workstations and there was one student per computer. The experiment was explained to the students verbally and again via the computer. Data was analysed using the Statistical Package for Social Science (SPSS 2002) to check for statistical difference among different conditions in the study. For this particular study *t-tests and Wilcoxon-matched sample tests* were appropriate, to test if there was significant *difference* between score-means. The *Pearson–rho* test was used to test the linear relationship between browsing times and increase in the score results. The choice of tests depends on the type of variables in the population, the number of samples and the type of the test (parametric or non-parametric). When reporting t-test results, two values are traditionally reported:

p-value (or observed significance level) is the probability (assuming that H_0 is true) of obtaining a value of test statistic that is at least as extreme as that actually obtained. It is the probability that the difference occurred by chance. Usually, if this is less than α=0.05 or 5%, the results are said to be statistically significant. **t-value** is the test statistic and it is calculated to determine whether to reject H_0. If the p-value is less than or equal to a specified α, H_0 is rejected. If the p-value is greater than α, H_0 is retained for want of evidence. Detailed discussion of hypothesis or significance testing can be found in most statistics textbooks (see Fowler *et al*, 1998). This study is an example of a crossover trial where matched or dependent samples were used.

The next section presents the results analysis divided into three parts: for all students, for 'balanced' students and for 'moderate' students.

6.5.1. Results analysis: All students

This section presents the performance results for the knowledge attainment and browsing times differences between matched and mismatched sessions. It also shows any dependency between the length of browsing times and the increase in scores achieved after browsing both sessions.

6.5.1.1. Knowledge score results: Difference between knowledge score means for matched and mismatched sessions for all students

To determine if the differences between mean variables (achievement scores) are significant, the two-sample, paired, 2-tailed **t-test** was used (appropriate, as the number of students was <30), which compares one variable between two groups. The main results are presented in Table 6.1.

Scores	Mean	N	Std. Deviation	Std. Error Mean
Q2	8.00	21	1.58	.34
Q4	5.09	21	1.84	.40

Table 6.1. The mean scores and standard deviation for all the students

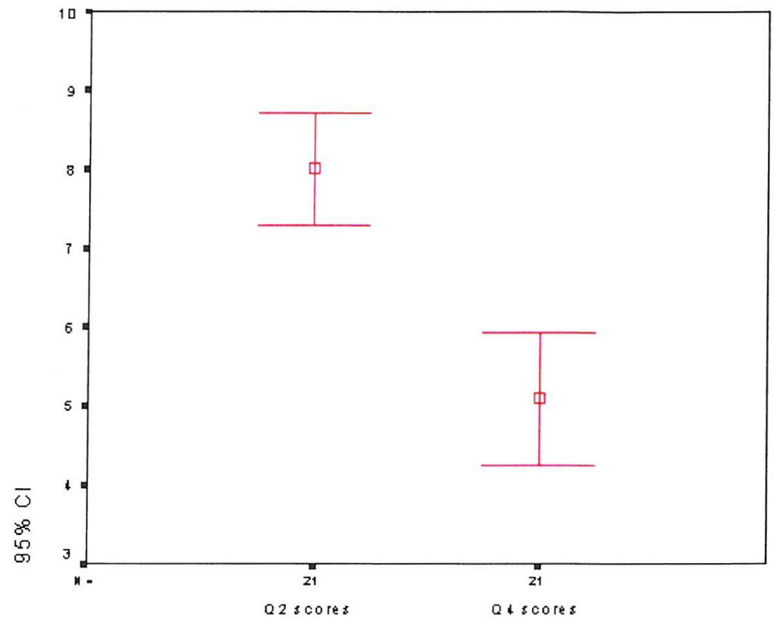

Figure 6.3. **Scores after the post-questionnaires with mean values for all students**

Figure 6.3. depicts the mean value of scores (Q_2) after matched session being much greater than the mean score value for mismatched session (Q_4).

Score difference		Mean	SD	SEM	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
	(Q2-Q4)	2.905	1.9469	.4249	2.02	3.79	**6.837**	20	**.000**

Table 6.2. SPSS results for the t-test for score differences for all students

The hypotheses for the test scores were that:

H_0: *Post-test-score means for matched and mismatched sessions are not significantly different*

H_A: *Post-test-score means for matched session are significantly higher than for mismatched session*

The mean values for scores after the 1st and 2nd session are listed in Table 6.1 and it shows that the mean scores for Q2 are much higher than for Q4 (8.00>5.09). Analysis of the student performance indicated that the students achieved higher scores when studying a matched session as opposed to a mismatched session. Mean values and standard deviation are also listed in the Table 6.1. From the post–test1 (after first session) and post-test2 (after second session) achievement scores it has been found that there was a very significant difference of correctly answered questions ($t(21)=6.84$; $p>0.000$, 2-tailed, Table 6.1.). The results indicate that there is statistically a very significant difference between the means of scores.

6.5.1.2. Browsing time results: Difference between browsing times for matched and mismatched sessions for all students

The *t-tests* and the *Wilcoxon matched pair* tests were performed for session browsing times. The completion times for browsing were measured from the start of each round until the students started answering post-tests. It was expected that the students would spend less time browsing their matched session than their mismatched session, as they were provided with adaptive navigation support.

1. ***t-test*** **results for browsing times**

Browsing times	Mean (mins.secs)	Number of students	Std. Deviation	Significance (2-tailed)
t1 (time to browse matched session)	18.87	21	13.87	3.028
t2 (time to browse mismatched session)	20.68	21	9.86	2.152

Table 6.3. SPSS results for t-test for browsing times for all students

The hypotheses for the browsing times for all students were:

H_0**:** *Browsing times for matched and mismatched sessions are not significantly different*

H_A**:** *Browsing time for a matched session is significantly shorter than for a mismatched session*

Table 6.3. shows that the means between two browsing times do not differ hugely, where t2>t1 (20.68>18.87mins**).** From Table 6.4 it can be noted that the results do not

indicate a significant difference between browsing times for the matched and mismatched sessions, i.e., t (21)=-0.495, p<0.626. This result indicates that students actually spent more time on their matched session compared to the mismatched session. The possible reason would be that the content was more engaging to them.

Browsing times difference	Mean	SD	SEM	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
t1 -t2	-0.80	16.69	3.64	-9.40	5.79	-.495	20	.626

Table 6.4. SPSS results for t-test for browsing times for all students

6.5.1.3. The Wilcoxon matched pair test results for browsing times

Considering the browsing times it was expected that the students would spend less time browsing the matched session than the mismatched session. This test takes into account the sign of the sample differences by ranking the data, i.e., it considers both, the sign of the difference and the magnitude of the difference.

The critical value of t (looked up in table, Morse, 1993) at p<0.05, is t (21)=67. The value obtained from ranking times (96) is higher than this critical value of t, so the result is not significant; which in turn indicates that the type of session did not affect the browsing times. In summary, data collected throughout the sessions indicated that there was not a significant difference between the means of browsing times between the matched and mismatched sessions, and therefore the evidence is found not to support the alternative hypothesis H_A. The table containing the calculation of the Wilcoxon matched pair ranks can be found in Appendix D.

6.5.1.4. Relationship between the length of browsing times and the scores for all students for matched and mismatched sessions

To check for any correlation between the length of browsing times between sessions and the scores achieved in the questionnaires, a *Pearson-rho* correlation coefficient was calculated. From the analysis of the results it can be noted that there are extremes in differences between the times spent browsing and the scores achieved. It appears that the students on average spent different lengths of time for the two different sessions and obtained different score increases. The score increases vary considerably compared with the amount of time that the students spent browsing the courseware. A significant number of the students (6) or 28% achieved the same scores after the 1st and 2nd session even though there is a high difference in the times they spent on average (15.93 mins). In one third of cases, the students spent a considerably longer time browsing the matched session (32.5mins on average), one half of them spent less time browsing the matched session (3.77 mins), and one sixth of them spent an almost identical amount of time on the two sessions and in this instance attained the same score. On average there was an 18.10% score increase for all the students between matched and mismatched sessions. The SPSS analysis provides the following results on the relationship between score increases and browsing times for all the students.

Matched session	Mean	SD	N
Q2-Q1 all students	3.43	1.66	21
t1 all students	18.26	13.69	21

Table 6.5a. Mean values of browsing times and score increase for all students for the <u>matched</u> session

Correlations between score differences (Q2-Q1) vs. t1 all		Q2-Q1 all	t1 all
	Pearson Correlation	1	.086
	Sig. (1-tailed)	.	.356
	N	21	21

Table 6.5b. *Pearson rho* test for the relationship between browsing times and score increase for all students for the <u>matched</u> session

Table 6.5b shows that the results from the analysis reveal that the Pearson's correlation coefficient is r=0.086, r^2=0.00739, or only 0.74 % of browsing time difference accounts for score difference, with a p-value of 0.356, which is clearly demonstrating not a very significant correlation. The Pearson rho (r) coefficient provides an index of the degree to which two variables are related. Its value can vary from 0 to 1. Positive value of 'r' in this case indicates that an increase in scores is accompanied by an increase in browsing times.

Mismatched session	Mean	Std. Deviation	N
Q4-Q3 all	2.33	1.713	21
t2 all	19.8200	9.37149	21

Table 6.6a. Mean values of browsing times and score increase for all students for the mismatched session

Q4-Q3 all vs. t2 all		Q4-Q3 all	t2 all
	Pearson Correlation	1	-.012
	Sig. (1-tailed)	.	.479
	N	21	21

Table 6.6b. Pearson rho test for the relationship between times and score increase for all students for the mismatched session

The results from Table 6.6b reveal that the Pearson's correlation coefficient is negative with the value of r=-0.12, r^2=0.0144, or 1.44 % of browsing time difference accounts for score difference, with a p-value of 0.479, which is clearly not demonstrating a very significant correlation. A negative value of 'r' in this case indicates that an increase in scores for all the students is accompanied by a decrease in the browsing times for the mismatched session. These results indicate that the post-test scores obtained in the study are not a reflection of the length of time that the students spent browsing the courseware.

This section presented the results on the knowledge scores and browsing time differences, as well as the relationship between score gains and the browsing times for all students.

The following section presents the results on the knowledge scores and browsing time differences for 'moderate' students (students who had moderate (5-7) and strong preferences (9-11) on Felder Silverman ILS scale). The results were expected to indicate whether 'moderate' and 'strong' students would benefit from tailored software that matched their learning preferences.

6.6. Result analysis: 'Moderate' students

6.6.1. Difference between means of scores of 'moderate' students

The following table shows how students were divided into 'moderate' and 'balanced' students.

	Number of students	
LSQ Scale[3]	Global Style	Sequential Style
1 (balanced)	3	2
3 (balanced)	3	4
5 (moderate)	5	2
7 (moderate)	1	0
9(strong)	0	1
11 (strong)	0	0

Table 6.7. The number of students with global or sequential learning styles on the Felder-Silverman LSQ scale

From Table 6.7 it can be seen that there were 9 (~38 %) so-called 'moderate' students. Since there was only one student with a very strong preference, he was added to the group of moderate students. The hypotheses postulated for 'moderate' students were the following:

H_0*: *Means of the scores for matched and mismatched sessions are not significantly different

H_A*: *Means of the scores for a matched session are significantly higher than for a mismatched session

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[3] *Note:* 1 and 3 denote 'balanced'-scale in this study (either global or sequential)

5,7,9,11 denote 'moderate'-scale in this study (either global or sequential)

Score difference	Mean	N	Std. Deviation	Std. Error Mean
Q2_'moderate'	8.00	9	1.41	.47
Q4_'moderate'	4.89	9	1.61	.54

Table 6.8a. Differences between scores after post-test questionnaires for matched and mismatched sessions for 'moderate' students

Score difference between matched and mismatched sessions	Mean	SD	SEM	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
Q2_'moderate' Q4_'moderate'	3.11	1.764	.588	1.76	4.47	5.292	8	.001

Table 6.8b. Means and standard deviations for the scores for 'moderate' students

Table 6.8a depicts the mean values for the scores after the 1st session (8.0) and 2nd session (4.89). It shows that the mean values for the matched session are much higher than for the mismatched session. Table 6.8b illustrates that the results are highly significant $t(8)=5.292$, $p<0.001$(2-tailed), therefore the null hypothesis H_0 can be rejected. The results indicate that the score means between matched and mismatched sessions for moderate students are significantly different.

6.6.2. Difference between means of browsing times for 'moderate' students

It was expected that the 'moderate' students would spend less time browsing their matched session than their mismatched session, as they were provided with the adaptive navigation support. The hypotheses for moderate students are:

***H_0**: Mean browsing times of 'moderate' students for matched and mismatched sessions are not significantly different*

***H_A**: Mean-browsing times of 'moderate' students for a matched session is significantly shorter than for a mismatched session*

Table 6.9a and Table 6.9b indicate the statistical results obtained.

Browsing time difference		Mean	N	SD	SEM
Moderate students	t1-' moderate'-MATCHED	14.78	9	8.68	2.89
	t2-' moderate'- MISMATCHED	13.95	9	9.33	3.11

Table 6.9a. Mean values and standard deviation for browsing times for 'moderate' students

Browsing time difference for moderate students	Mean (mins)	SD	Std. Error Mean	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
t1-' moderate' – t2-' moderate'	.82	16.40	5.47	-11.78	13.43	.151	8	.884

Table 6.9b. SPSS results for t-test of browsing times for 'moderate' students

Table 6.9a illustrates the mean values for the browsing times for matched and mismatched sessions. They do not appear to differ greatly ($14.78_{matched} > 13.95_{mismatched}$ mins) and browsing times for the mismatched session appear to be shorter than for the matched session, which supports the H_0 strongly. The data does not provide conclusive evidence that justifies rejecting H_0 at the previously set level of significance, $t(8)=0.151$, $p<.884$. A 95% confidence interval of the difference is wide, ranging from –11.78 to 13.43.

6.6.3. Correlation between score gains and the length of browsing times for moderate students

This section presents the Pearson rho-correlation coefficient results for balanced students. Table 6.10a presents the mean values of browsing times and score gains for moderate students.

Matched session	Mean	Std. Deviation	N
(Q2-Q1) moderate	3.44	1.94	9
t1_moderate	14.78	8.68	9

Table 6.10a. Mean values of browsing times and score increase for 'moderate' students for the matched session

Matched session: score increase vs. browsing time $t1_{\_matched}$		$Q2\text{-}Q1_{moderate}$	$t1_{moderate}$
Correlations $(Q2\text{-}Q1)_{moderate}$ vs. $t1_{\_moderate}$	Pearson Correlation	1	.007
	Sig. (1-tailed)	.	.493
	N	9	9

Table 6.10b. Pearson rho test for the relationship between times and score increase for 'moderate' students for the matched session

From Table 6.10b it can be seen that positive correlation coefficient is very small r=0.007, p=0.493, r^2=0.000049 or ~0.0049% of browsing time difference accounts for the score increase within the *matched* session. Since p is large, the data does not give us any reason to conclude that the correlation is significant.

Mismatched session	Mean	Std. Deviation	N
(Q4-Q3) moderate	2.44	1.24	9
t2 moderate $_{mismatched}$	13.95	9.33	9

Table 6.11a. Mean values of browsing times and score increase for 'moderate' students within mismatched session

Mismatched session: score increase vs. browsing time t2 Correlation		$Q4\text{-}Q3_{moderate}$	$t2_{moderate}$
$(Q4\text{-}Q3)_{moderate}$ vs. $t2_{\_moderate}$	Pearson Correlation	1	.440
	Sig. (1-tailed)	.	.118
	N	9	9

Table 6.11b. Pearson rho test for the relationship between times and score increase for 'moderate' students within mismatched session

From this table it can be seen that correlation is positive $r=0.440$, $p=0.118$, $r^2=0.1936$ or ~19.36% of browsing time difference accounts for the score increase within the *mismatched* session. These results provide a very modest correlation between browsing times and score increases for 'moderate' students. The next section presents the results analysis for the 'balanced' students.

6.7. Results analysis for 'Balanced' students

6.7.1. Difference between means of scores of 'balanced' students

The following section presents the results for the knowledge scores and browsing time differences for 'balanced' students (students who had balanced preferences (1-3) on the Felder Silverman ILS scale). There were 12 such students. According to Felder and Silverman (1988), such students are well balanced on both dimensions of the global-sequential scale. Such students are expected to perform equally well, regardless of whether the teaching environment supports their preference or not. Therefore, the hypotheses postulated for this type of student were as follows:

H_0: Means of the scores of 'balanced' students for a matched session are significantly higher than for a mismatched session

H_A: Means of the scores of 'balanced' students for a matched session are NOT significantly higher than for a mismatched session

	Mean	N	Std. Deviation	Std. Error Mean
Q2-balanced	8.00	12	1.76	.50
Q4-balanced	5.25	12	2.05	.59

Table 6.12a. Mean values and standard deviation for knowledge scores for 'balanced' students

Score differences for 'balanced' students	Scores					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval				
				Lower	Upper			
Q2-balanced –Q42-balanced	2.75	2.18	.61	1.39	4.11	4.457	11	.001

Table 6.12b. SPSS results for knowledge score for balanced students

Table 6.12b presents the difference between means of scores for 'balanced' students. The results indicate t (11)=4.457, p<0.001 that 'balanced' students have achieved higher scores in matched sessions, contrary to expectations. Such students did not have any strong preference for either learning environment and therefore should have performed equally well.

6.7.2. Browsing time differences for 'balanced' students

It was expected that the 'balanced' students would not spend less time browsing their matched session than their mismatched session, *i.e.,* they were not expected to be affected by the difference in learning environments. The hypotheses for balanced students are:

H_o: *Mean browsing times of 'balanced' students for matched and mismatched sessions are significantly different*

H_A: *Mean-browsing times of 'balanced' students between matched and mismatched sessions are not significantly different*

Browsing times	Mean	N	Std. Deviation	Std. Error Mean
t1-balanced	20.87	12	16.38	4.73
t2-balanced	24.22	12	6.86	1.98

Table 6.13a. Mean values and standard deviation for browsing times for 'balanced' students

Browsing times difference	Mean (mins)	SD	SEM	95% Confidence		t	df	Sig. (2-tailed)
				Lower	Upper			
t1-balanced - t2-balanced	-3.35	17.37	5.01	-14.38	7.68	-.669	11	.518

Table 6.13b. Mean values and standard deviation for browsing times for 'balanced' students

Table 6.13b indicates that the results for the browsing times for balanced students indicate $t(11)=-.669$, $p<.518$ implying that the null hypothesis H_o can be rejected, *i.e.*, the browsing times between the two sessions for 'balanced; students are not significantly different.

6.7.3. Browsing times difference versus score increase for 'balanced' students

The hypotheses for the case of 'balanced' students were as follows:

H_0: *'Balanced' students will achieve significantly higher scores when browsing a matched session for a shorter time*

H_A: *'Balanced' students will not achieve significantly higher scores when browsing a matched session for a shorter time*

Matched session	Mean	Std. Deviation	N
(Q2-Q1)_ balanced	3.42	1.50	12
t1 balanced	20.87	16.38	12

Table 6.14a. Mean values and standard deviation for 'balanced' students for the matched session

Matched session		(Q2-Q1) balanced	t1 balanced
(Q2-Q1) $_{balanced}$ versus t1 $_{balanced}$	Pearson Correlation	1	.143
	Sig. (1-tailed)	.	.328
	N	12	12

Table 6.14b. Pearson rho test for the relationship between time and score increase for 'balanced' students (1-tailed) for the matched session

Table 6.14a presents the mean value and standard deviation for the mean score difference for browsing times and test scores for 'balanced' students. Table 6.14b. shows the value of p=0.328,with a positive correlation coefficient r=0.1443 and $r^2=0.020$ or 2% of time difference accounts for score difference within matched session. The value of r provides compelling evidence that there is no significant correlation between browsing times difference and score increases for 'balanced' students.

Mismatched session	Mean	SD	N
(Q4-Q3) balanced	2.25	2.05	12
t2 balanced	24.21	6.86	12

Table 6.15a. Mean values and standard deviation for 'balanced' students for a mismatched session

Correlations between score gains and browsing time in mismatched session		Q4-Q3 balanced	t2 balanced
(Q4-Q3) balanced $_{mismatched}$ vs. t2 balanced $_{mismatched}$	Pearson Correlation	1	-.221
	Sig. (1-tailed)	.	.245
	N	12	12

Table 6.15b. Pearson rho test for the relationship between time and score increase for 'balanced' students (1-tailed) for a mismatched session

Table 6.15a shows the mean value and standard deviation for the mean score difference for browsing times and test scores for 'balanced' students. Table 6.15b shows the value of p= 0.245,with a negative correlation coefficient r=-0.221 and r^2=0.048 or a 4.84% of time difference accounts for score difference within mismatched session. This very weak negative correlation indicates that as the browsing time increased, the score increase became smaller for balanced students.

6.8. Summary of the results

1. <u>All students</u>

First alternative hypothesis H_A was confirmed. All the students achieved significantly higher scores while browsing the matched session for all students, t (20)=6.837, p<0.000 (two–tailed).

Second alternative hypothesis H_A was not supported. Browsing times for the matched session are not significantly shorter than for the mismatched session for all the students, t (20)=-0.495, p<0.626.

Third alternative hypothesis H_A was not supported. All students did not achieve significantly higher scores in a shorter time period, that is there was not a strong correlation for the matched session r = 0.086, p<0.356, nor for the mismatched session r=-0.012, p<0.479.

2. <u>Moderate students</u>

First alternative hypothesis H_A was confirmed. Moderate students achieved significantly higher scores while browsing the matched session, t (8)=5.292, p<0.001 (two–tailed).

Second alternative hypothesis H_A was not supported. Browsing times for matched session are not significantly shorter than for the mismatched session, t (8)=.151, p<0.884

3. <u>Balanced students</u>

First alternative hypothesis H_A was NOT confirmed. Balanced students did achieve significantly higher scores while browsing the matched session, t (11)=4.457, p<0.001 (two–tailed).

Second alternative hypothesis H_A was supported. Browsing times between matched and the mismatched sessions are not significantly different, t (11)=-.669, p<0.518 (2-tailed).

6.9. Discussion

The main goal of this empirical evaluation was to evaluate if there was a very significant difference in the scores achieved in the adaptively matched-learning-style-session versus the mismatched-learning-style-session. We also tested for the relationship between the score gains achieved between matched and mismatched hypermedia environment and browsing times between the two sessions. Results obtained indicate insightful data with respect to the student's preferences about learning. The following discussion concerning the identified factors provides an insight into possible reasons for these findings. The following can be derived from the experimental findings:

i) Knowledge scores from post-tests: difference between means of post- scores matched versus mismatched session

In analysing the responses to the test questions, the scores for two session types suggested that there was a strong relationship between matching students' learning style to the courseware as the results suggest that all the students achieved significantly higher scores while browsing the session that matched their learning styles.

For 'balanced' students the difference between means of scores indicates that both 'moderate' and 'balanced' students benefited from tailored courseware. The expectation was that there would not be a significant difference in the scores for balanced students, as they do not have a very strong learning preference. The results indicate that this was not the case. One of the reasons may be the 'sensitivity' of the ILS scales. The authors would like to state that at the time of conducting the study that the validity and reliability of Felders' ILS was still under evaluation. In a recent study by Zywno (2003) the ILS responses were collected from several hundred engineering students and assessed test-retest reliability, internal consistency reliability, and several quantities related to the independence and construct validity of the four instrument scales. Zywno (2003) concluded that the ILS meets criteria of acceptability for instruments of its type.

Table 6.16 presents a summary of score results obtained for all students, as well as the results analysed for 'balanced' and 'moderate' students.

Mean Scores					
Adaptive Session type	Student type	Mean scores	SD	t-test difference	Significance (2-tailed)
Matched (M)	All	8.00	1.58	6.837	p<0.000
	Moderate	8.00	1.41	5.292	p<0.001
	Balanced	8.00	1.76	4.457	p<0.001
Mismatched (MM)	All	5.09	1.84		
	Moderate	4.89	1.61		
	Balanced	5.25	2.05		

Table 6. 16. A summary of the results obtained in the study for the mean values, standard deviation, t-test and significance levels for scores

ii) The browsing time differences between matched versus matched sessions

With regards to the difference in mean browsing times between the two sessions, the evidence suggests that there is no significant difference between the lengths of time the students spent on the two sessions. On average the time it took to browse the matched session was only slightly different than the time it took to browse the mismatched session for all the students. For 'moderate' students the means for browsing times show that there was a very small difference (14.778>13.954 mins) between the matched and mismatched sessions, and $t(8)=0.151$, $p<0.884$ (2-tailed). For 'balanced' students that difference was small indicating that 'moderate' students needed slightly longer time to browse their matched session. This time difference was not particularly pronounced (1.56 mins). The speculation would be that since the first session was tailored to suit their preferred way of learning, it grabbed their attention for a longer period of time. This can also possibly be caused by that fact that their attention span was shorter in the mismatched sessions and also that their enthusiasm waned in the second session (mismatched session).

Mean browsing times for the matched sessions were on average shorter for 'balanced' students. This difference was not particularly pronounced but it was more than double the time of the strong students (3.35 mins). The conclusion is that there was not a statistically significant difference between browsing times for the matched and mismatched sessions. Table 6.17 presents a summary of browsing times obtained for all students, for 'balanced' and 'moderate' students.

Browsing times					
Session type	Student type	Mean times (mins.secs)	SD	t-test of difference	Significance (2-tailed)
Matched (M)	All	18.87	13.87	-0.495	p<0.626
	Moderate	14.78	8.69	0.151	p<0.884
	Balanced	20.87	16.38	-0.669	p<0.518
Mismatched (MM)	All	20.68	9.86		
	Moderate	13.95	9.33		
	Balanced	24.22	6.86		

Table 6.17. A summary of the results obtained in the study for the mean values, standard deviation, t-test and significance levels for the browsing times

The lack of any significant difference between browsing times for the matched and mismatched groups may be due to a number of factors. The results indicating that browsing times are not affected by the session-type may seem surprising, but a closer examination shows that it is not unreasonable. It may be suspected that the students who were not 'burdened' with the additional links and learning style elements (in the sequential session) may perform slightly faster when browsing, but their scores indicate otherwise. In fact the results do not indicate a trend towards lower times. The amount of information displayed on the screen within the global session might have an impact on the browsing times too, although that is not to say that the browsing tasks in sequential sessions were not less cognitively demanding. Other factors such as reading speed might have affected the browsing times. It is also possible that one of the subjects was more difficult to process and comprehend.

iii) The browsing times versus score difference increase

The data analysed indicated that there was not a correlation between the students' performances and browsing times. Browsing times have shown not to affect the increase in scores after each session. 24% of the students achieved a higher score difference in shorter time. Those students who spent longer times (19%) browsing the matched session achieved higher mean scores, while those students who spent less time browsing the matched session (5%) achieved lower scores.

Table 6.18 presents a summary of the correlation coefficients calculated for all students, and 'balanced' and 'moderate' students.

Pearson rho (r) coefficient					
Session type	**Student type**	r	r^2	%	**p(1-tailed)**
Matched (M)	**All**	0.086	0.0074	0.74%	p<0.356
	Moderate	0.007	0.000049	0.0049%	p<0.493
	Balanced	0.143	0.020	2%	P<0.328
Mismatched (MM)	**All**	-0.012	0.014	1.44%	P<0.479
	Moderate	0.440	0.1936	19.36%	p<0.118
	Balanced	-0.221	0.048	4.8%	p<0.245

Table 6.18. A summary of the Pearson rho (r) coefficients calculated in the study

The average score increase for all the student was 18.1%, compared to 16% for 'moderate' students and 18.3% for 'balanced' students. It was expected that 'balanced' students would do equally well in both sessions. However, it appears that 'balanced' students had higher score increase than 'moderate' students. It can be speculated that the number on the Felder-Silverman ILS scale was not as important as the fact that the students fall into one or the other learning preference categories. Explanations for this can include that perhaps the Felder-Silverman instrument is not sufficiently sensitive to identify the students' dominant learning style. Based on the findings of this study, there was no conclusive evidence to support the null hypotheses postulated at the start, which read that 'moderate' students should achieve higher scores and another one that 'balanced' students should score equally well in both sessions, as according to Felder-Silverman LSQ they are fairly well 'balanced' on two dimensions on that scale.

Other factors which may have affected this relationship or limitations of the study, could be the following:

Reading speed. It has been found that the reading speed may influence student performance (Hong Ng, *et al.* 2001). The reading speed of the students was not measured prior to this experiment but this factor should not be neglected.

Motivation. This is another important factor which may explain why the browsing times and the score difference did not relate. We can speculate that for some students this experiment would prove a challenge, while some of them realised that the experiment-results would not be taken into account for their GCSE result; therefore there was a lack of motivation to spend enough time browsing and understanding the courseware.

Content interest level. The subjects chosen for this study may not have appealed to all the students and held little interest for some students.

Summary

This was an initial study evaluating the impact that learning-style-adaptation within hypermedia has on learning outcomes. In the case of this study, with its emphasis on GCSE students, the main hypotheses postulated regarding the mean scores difference were found to be particularly pertinent and well founded.

The results suggest that the students benefit from the learning materials being adapted to suit their learning preferences. The highly significant results achieved by the students are seen as a means for providing a good foundation to proceed with this type of adaptation. The findings are consistent with the results presented by Pillay *et al.* (1996) within non-adaptive hypermedia environment, where the students performed better when instructional material matched the student's preferred cognitive style, than those who received mismatched instruction (66% versus 62%).

The next chapter presents a literature review regarding learning strategies, building on the work presented so far.

Chapter 7. Learning strategies in hypermedia

7.1. Introduction

This chapter builds on the previous work regarding learning styles and extends to learning strategies that students may employ while learning using hypermedia materials. Over the past 20 or so years there has been an emphasis placed on learners and what kind of strategies they employ to understand and learn information. The purpose of this chapter is to identify a theoretical framework to classify learning strategies and to determine specific ones that may be useful in learning in adaptive hypermedia environments. This chapter provides the background of cognitive learning strategies, and gives definitions of various learning strategies, with particular focus on two 'complex' types of learning strategy.

7.2. Stable styles versus changeable strategies

Many researchers see learning styles as a characteristic of an individual that stays fixed over a period of time, while learning strategies are seen as characteristics that are adaptable and changeable over time. Keefe (1979) described learning styles as the interaction of “cognitive, affective and psychological traits” that serve as ...”relatively stable indicators of how learners perceive, interact with, and respond to the learning environment”. Claxton and Ralson (1978) regarded learning styles as “a student’s consistent way of responding and using stimuli in the context of learning”. Riding and Cheema (1991) see learning styles as a “fixed characteristic" of an individual that is static and stable. Similarly, Laing (2001) states that "styles are fixed but strategies are adaptable processes we can use to respond to the demands of a learning situation". Sadler–Smith (1996) distinguishes learning style as " a distinctive and habitual manner of acquiring knowledge, skills or attitudes through study or experience". Riding and Douglas (1993) state that

> *"... strategies are the ways that may be used to cope with situations and tasks. They may vary from time to time and may be learned and developed. Styles, by contrast, are static and relatively in-built features of an individual".*

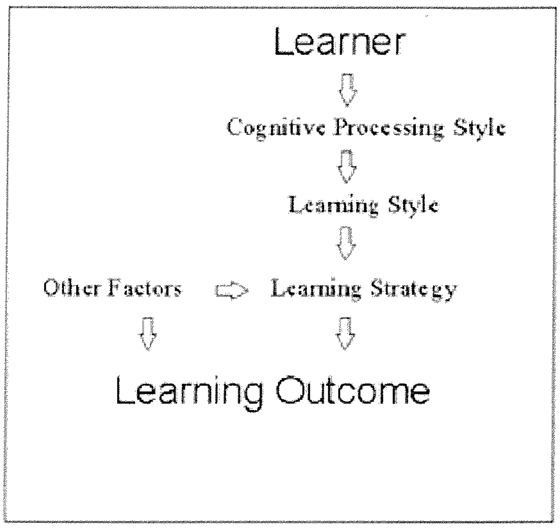


Figure 7.1. Learner characteristics affecting learning (Lord 1998)

Lord (1998) sees both learning styles and learning strategies as characteristics that both influence and affect learning outcome. Learning strategy is according to Lord "a plan of action adopted in the acquisition of knowledge, skills and attitudes through study or experience". Sadler-Smith and Riding (1998) assert that "learning styles can be viewed as a halfway house between the relatively fixed modes of cognitive processing and the adaptable learning strategy adopted for different learning tasks". McKeachie (1995) argues that 'the "learning styles are preferences and habits of learning that have been learned...regardless of their learning styles, the students can learn strategies that enable them to be effective". Strategies can be learned and modified while style is relatively fixed core characteristic of an individual (Riding and Ryner, 2002).

7.3. Learning strategy definition

A number of definitions of learning strategies have been used in the field of educational psychology. Early on, Weinstein and Mayer (1986) defined a learning strategy as "thoughts and behaviours intended to influence the student's ability to select, acquire, organise and integrate new knowledge". More specifically, a learning strategy is an individual's way of organizing and using a particular set of skills in order to learn content or accomplish other tasks more effectively and efficiently in school as well as in non-academic settings (Schumaker and Deshler, 1992). Park (1995) defined learning strategies as "mental activities that people use when they study to help themselves acquire, organize, or remember incoming knowledge more efficiently". Riding and Ryner (2002) state that

> *"a learning strategy is a set of one or more procedures that an individual acquires to facilitate the performance on a learning task. Strategies will vary depending on the nature of the task. Learning strategies are formed as part of a response within the individual to meet the demands of the environment. Learning strategies may thus be sees as cognitive tools which for the individual are particularly helpful for successfully completing a specific task".*

The reviewed literature shows that a large number of learning strategies have now been identified and teachers have been encouraged to enable the students to use a variety of learning strategies in secondary education. The majority of the research on cognitive strategies focused on language learning (Oxford, 1990), reading comprehension (Alvermann and Moore, 1991), text comprehension (Pressley and Woloshyn, 1995), problem solving, and study skills. Palinscar and Brown (1986) successfully tested and replicated reciprocal teaching, a strategy to improve the student's reading performance. The focus of reciprocal teaching is split into four strategies: summarisation, predicting, questioning and seeking clarification. The process initially involves the modelling of these strategies by a teacher and then the gradual release of responsibility to the students.

Some research reports that the students naturally apply effective strategies, however Palinscar and Brown (1986), Jonassen (1985) and Rosenshine (1997) suggest that these strategies ought to be first taught. Procedures for teaching such strategies included the use of concrete prompts (checklists, cue cards, concrete prompts) and instructional procedures, completing part of the task for the students, presenting material in small steps and suggesting 'fix-up' strategies. The essence of these methods would be 'scaffolding' students as they develop internal structures.

Oxford (1990) presented different categories in language learning strategies: cognitive, metacognitive, memory-related, compensatory, affective and social strategies. Cognitive learning strategy includes: deductive reasoning, analysing, taking notes, highlighting and summarising, among others. Meta cognitive learning strategy relates to organising and setting objectives and evaluation of one's own performance. Memory-related learning strategy refers to creating mental linkages and structured reviewing of words. Compensatory learning strategy includes selection of a topic to avoid unknown vocabulary. Affective learning strategy implies making positive statements about one's own progress. Finally, social learning strategy includes asking for clarification and working with peers. Oxford draws attention to the fact that some of these strategies are guided by external influences, such as interaction, activities and teachers, while others are related to students' awareness and knowledge about how to learn.

One of the most comprehensive reviews of learning strategies is that of Weinstein and Mayer (1986), who divided cognitive strategies into three categories:

- Rehearsal strategies, employed to remember material using repetition.
- Organisation strategies, where the students organise and select the main ideas of material through the process of outlining and making diagrams
- Elaborative strategies, where the students build a connection between what has been learned already with previous knowledge through the process of summarising and question answering, among other techniques.

Category: Learning strategies	Definition
Basic Rehearsal strategies	Repeating item names for remembering
Complex Rehearsal	Copying, underlining, shadowing material
Basic elaboration strategies	Forming mental images or sentences relating information
Complex elaboration strategies	**Paraphrasing, summarising, or describing now new information related to prior knowledge**
Basic organisational strategies	Grouping or ordering information
Complex organisational strategies	Outlining, hierarchy development
Comprehension monitoring strategies	**Checking for comprehension failures or for understanding**
Affective and motivational Strategies	Student behaviour and attitude alert, relaxed, interested, positive

Figure 7.2. Categorisation of learning strategies according to Weinstein and Mayer (1986)

From Figure 7.2 it can be seen that learning strategies take the form of basic and complex rehearsal, basic and complex elaboration, basic and complex organisational learning, comprehension monitoring and affective strategies. The goals of these techniques include the integration of presented information with prior knowledge, according to Weinstein and Mayer (1986). Once the students develop a repertoire of routines associated with strategic learning, they would achieve far higher levels of effective and efficient learning.

7.4. Historical development of identifying learning strategies

Research in cognitive science has long been examining a variety of cognitive processes involved in learning and the educational environments that can foster those processes. The research in the past twenty years has acknowledged the importance of learning strategies and many studies examined their efficacy. This cognitive research was taking shape in the late 1970s as Gagne (1977) began to use the 'cognitive strategies' term. There is classification of learning strategies into cognitive, metacognitive and affective strategies. The strategies selected for this study are often referred to as reading comprehension strategies (Levine 1994), comprehension monitoring strategies (Weinstein & Mayer 1986), cognitive strategies (Park, 1995) or critical reading strategies (Hardcastle, 1995); it is very difficult to identify a critical distinction and in some case the terms are used interchangeably and overlap to some extent. Hammond (1993) argues that hypermedia-based learning makes assumptions about metacognitive skills, in particular "it supposes that learners can make well motivated choices over the sequencing of exposure to materials and the best strategy for organising learning activities". A number of powerful cognitive strategies can be used to enhance learning and performance, such as activating background knowledge, generating questions, summarising, imaging, predicting, visualising, monitoring comprehension, creating analogies, organising information into patterns, prioritising and so forth. These strategies are also used for processing information effectively. The strategies that students employ when learning depend on many factors, such as learning styles, motivation, type of task, and age, as was found when language learning (Oxford, 1990).

7.5. Educational hypermedia and the application of learning strategies

A growing body of research suggests to us how learners construct meaning and how teachers can effectively teach the students, to combine their personal knowledge and experience with information to construct meaning as they read. Instructional strategies such as activating the students' background knowledge, along with the strategies of summarizing, clarifying, questioning, predicting, and evaluating can help the students learn more from hypertext and hypermedia. Recker and Pirolli (1994) say that 'learners employ a wide variety of strategies when faced with learning and problem solving in a new domain.'

Individuals tend to develop learning strategies in order to deal with learning materials and therefore learning strategies can be regarded as cognitive tools, which enable students to complete tasks and solve problems (McLoughlin, 1999).

The most effective learners would use multiple strategies to ensure that they monitor their comprehension as they browse hypertext. "Frequent comprehension checks are an important part of an effective learning process. This is particularly important in the hypermedia environment, where students can get easily distracted and lose coherence of what they are reading" (Foltz, 1996). Fragmentation in hypertext makes it more difficult to perceive the author's intended argument structure (Whaley 1993). McLoughlin (1999) emphasises that, "by relating the research on learning strategies to the design of learning environments it is possible to investigate how learners approach their learning". Park (1995) has synthesized the research on learning strategies from the field of cognitive psychology and pointed out that the strategies such as summarisation and questioning are "strongly effective" strategies. He also suggested that those strategies could be applied in computer-assisted instruction. Plowman (1988) suggested that "passive learning strategies need to be bolstered by cognitive enhancers... environments in which the student is given tools to 'repurpose' existing materials... and allow more opportunity for engagement". Schmeck (1988) defined a learning strategy as "a pattern of information processing activities used to prepare for a test of memory". Paterson and Rosbottom (1995) state that "learning strategies are methods employed by the learner to achieve learning".

7.6. Learning strategies and effective learning

According to Stern (1992), "the concept of learning strategy is dependent on the assumption that learners consciously engage in activities to achieve certain goals, and learning strategies can be regarded as broadly conceived intentional directions and learning techniques". He states that the strategies are used "consciously or unconsciously when processing new information and performing tasks" in the classroom. Applying inappropriate learning strategy or not knowing how to apply a learning strategy for learning concepts may prove a big stumbling block for some students and is likely to hamper their comprehension. The students can make individual decisions about their learning strategy when working through hypermedia material. The successful comprehension of the material depends on students' activating the relevant strategy.

However, there is very little evidence that shows that explicit attention is paid to emulating learning strategies in the hypermedia environment and encouraging the students to apply them. Mayes (1994) points out that unless the browsing is motivated by seeking answers to questions, it will only support a shallow learning experience. He goes on to suggest that "interaction must be at the level of meaning, whereby the learner seeks answers to new questions, arranges the material into new structures, or performs other manipulations which succeed in raising the level of comprehension".

Not all learning strategies have proven to be effective. Ellis and Lenz (1987) have identified some critical features of strategies that are effective for students, such as content (describes the steps used to encourage the use of strategy), design (describes how to place steps together for strategy use) and usefulness of strategies (transfer of strategy to other settings and conditions).

'Content features' contain the following important points:

1. Effective learning strategies contain a set of steps that lead to a specific and successful outcome.
2. The steps of an effective strategy are sequenced in a manner that leads to an efficient approach to the task.
3. The steps of an effective strategy cue the students to use specific cognitive strategies

"Effective learning strategies often are 'strategy systems' incorporating many cognitive strategies such as activating background knowledge, generating questions, summarising, imaging and so forth" (Ellis and Lenz, 1987).

7.6.1. Mapping cognitive learning strategies: Content presentation, structural and strategy cues

Authors of hypermedia courseware face a challenge of learning strategy representation. It is a well-known factor that the students are aware of textual features of hypermedia courseware. This does not refer only to the syntax vocabulary but also the arrangements of ideas in text. Van Dijk and Kintsch (1983) state that coherence is assisted by the use of well-defined structure and appropriate cues to indicate the structure to the reader. Similarly Thüring, Mannemann and Haake (1995) have conducted a study in text and have found that significant structure enhancements were made by using cues of hypermedia courseware. Oliver and Herrington (1995) suggested that as an aid to increasing understanding, the hypermedia system could be made to provide inferential and literal questions together with paragraph summaries. Summaries and questions are seen as cues. Blohm (1982) found that the use of cues such as summaries could enhance the learning and recall of information. When designing hypermedia courseware authors need to implement a variety of linking mechanisms, coupled with structuring materials appropriate for the learning outcomes and individual learning differences among the students, as well as the use of cues to indicate appropriate learning strategy.

Effective learning involves knowing when to use a specific strategy, how to access that particular strategy, as well as when to abandon an ineffective strategy (Jones *et al.,* 1987). One method or learning strategy may be ineffective for some students who could learn more effectively using a different strategy. Having said that, many students are not aware of what strategies work for them. Some students may experience difficulty in selecting the main idea or the concept and supporting details. They treat each sentence with the same importance. Learning will be easiest when there is a strong correlation between the way in which new material is presented to us and our learning preferences. Conversely, we find learning more difficult when there is a large disparity between our learning strategy preference and the supplied learning presentation (McKeachie, 1995).

The students modify strategies depending on a number of factors including learning context. Bork (1991) asserts that strategies can vary enormously - they can use different media, they can use different pedagogical directions and they can be tailored in different ways to individual differences. When the students incorporate learning tactics into their learning strategies, they are tailoring their strategies to assist themselves in achieving learning objectives. The type of learning strategy adopted by a student could affect which cognitive tools are selected and their frequency of use when a student implements a learning strategy.

7.7. "Complex" learning strategies: Summarising and Questioning

According to Nist and Simpson (2002), research-validated strategies are small in number, however, extensive research for the past two decades indicates that some of the strategies for constructing meaning are more significant than others (Dole *et al.*, 1991). "Many learners know little of what strategies and techniques they naturally tend to use when learning something new. Strategies can be simple or complex, unconsciously applied or used with great awareness or deliberation" (News Digest **25**, 2002). A study has been conducted to examine which learning strategies students use (McLeod *et al.*, 1998). It was found that many students made good use of 'complex' (Weinstein and Mayer, 1986) learning strategies such as "questioning" and "summarisation". These two techniques have been shown to help the students develop higher-level reading comprehension skills. (Bos and Filip, 1984). Rosenshine (1997) wrote that a cognitive strategy is " a guide that serves to support or facilitate the learner as she or he develops internal procedures that enable them to perform the higher level operations". According to Rosenshine (1997) higher-order tasks do not have fixed sequence like well-structured tasks. One cannot develop algorithms that students could use to complete higher-order tasks.

The "questioning" (Q) or question generating strategy enables students to generate questions and identify the kind of information that is significant enough to provide the substance for a question. The students reflect on the read material by reflective questioning. This strategy has also proved to be valuable in constructing meaning (Davey and McBride, 1986). Winograd (1984), and Duke and Pearson (1991) listed questioning and summarising strategies as cognitive strategies. These two learning strategies have also proved to be effective in textbooks (Ryan 1984, Park 1995). Research indicates that these two strategies are important in helping readers construct meaning. Each of these strategies helps the students to construct meaning from text and monitor their reading to ensure that they in fact understand what they read. The questioning strategy, on the other hand, presents the students with an opportunity to reflect on the material that they have read. When the students generate questions about what they have read, they are actively processing text information and monitoring their understanding of that information (Nist and Simpson, 2002).

The "summarizing" strategy (S) provides the opportunity to identify, paraphrase, and integrate important information. This strategy, which involves the students having to pull the important information from the text, has proved useful in constructing meaning (Brown and Day, 1983). The summarizing strategy provides the students with the opportunity to identify, paraphrase, and integrate important information in the text. Summarisation as a strategy has taken many forms over the years. Nist and Simpson (2002) incorporated the summarisation strategy by asking the students to write brief summaries in the margins of text.

Ausubel (1978) has shown that the use of questions before, during and after instruction increases the degree of learning. Schank (1994) has in particular investigated learning achieved by inquiry and exploration in hypermedia environments. He states "when students become involved with a subject, they naturally generate questions". Alvermann (1991) focused on the role of the student's self questioning in constructing knowledge about science texts.

One of the major problems in using hypertext or hypermedia for learning outlined by Allison and Hammond (1989) was inefficient learning strategies. To promote flexible strategy employment, opportunities for the students to reflect and evaluate should be created (Campione *et al.* 1995).

Gerjets *et al.* (2000) examined the adaptive selection of strategies in learning from worked-out examples within a hypertext–based learning environment. They suggested that "adaptive selection of strategies should be of major importance for success in learning and problem solving."

In relation to implementing effective learning strategies in a hypermedia environment, a novel approach to the design of hypermedia systems is required Jonassen (1988). He suggested that learning strategies could be embedded inside a hypermedia program as a study skill and to encourage strategy use. According to Jonassen (1988), a hypermedia environment provides ideal conditions in which different learning strategies can be applied to promote effective learning. Hsiao (1997) conducted a combined study in which learning strategies (such as note-taking, summarisation, reflective questions) were embedded into hypermedia based systems. The author also embedded prompts to encourage the strategy use, and combined the study with the application of cognitive styles. Research indicated that embedding learning strategies in software was effective as the students with the learning strategies embedded performed better (Thornburg and Pea, 1990).

7.8. Learning strategies and adaptivity

While studies in effective learning strategies continue to emerge, the relevance of applying these strategies in the field of adaptive hypermedia learning has not been determined. Adaptive hypermedia environments have good potential to assist in the use of learning strategies and therefore fostering comprehension and learning. Adaptation of hypermedia instruction is one of the best ways forward to meeting individual student needs. The adaptation can be achieved through presenting the same content through differently applied learning strategies. The essence of adaptation is not directing the learner but a "scaffolding" of the learner as they interact with the system, which assists them in developing internal structures According to Hammond (1993) basic hypertext systems may fail to provide students with the support, direction, and engagement that learning requires. This failure suggests implications for the design of hypetext-based learning and the introduction of adaptivity. The success of adaptive systems can be measured if they can cognitively adapt to the student. Duchastel (1992) states that "hypermedia systems do not adapt cognitively to the student: this is their weak point". The adaptive system can attempt to emulate the actual processes employed by students for effective learning. Wang *et al.* (1997) have proposed an adaptive implementation of cognitive learning strategies for medical students by supporting concept mapping. A map could be a drill and practice slide box or a set of problem-based learning examples. The system is intended to be used by educators allowing them to refine their teaching strategies. The system would support expositor, practice and problem-oriented strategies.

Bull (2000) created an adaptive system that recommended individual language learning strategies in order to help the students become more effective learners. The student model combined the representations of learning styles and current strategy use. A new strategy was recommended based on the information obtained from the student model. The recommended strategies were from cognitive, metacognitive and memory domains. Karagiannidis *et al.* (2001) suggested that adaptive learning environments advocate that the learning context should be adapted to the individual student, as opposed to traditional learning settings, where it is the student's responsibility to adapt to the learning context in order to maximise the 'learning outcome'. Because hypertext learners are sifting through a huge amount of data, they use different reading and learning skills and strategies than when using an ordinary textbook. Conati (1999) designed an adaptive system that provides adaptive support to learning from examples by coaching the meta-cognitive skill known as self-explanation. In the TANGOW system, developed by Carro *et al.* (1999) two learning strategies are used to achieve adaptivity -'theory presentation or practical exercises'. The students could select their preferences at the start of the experiment.

Li *et al.* (2001) created the LEGATS system where they incorporated adaptable tutoring strategies, where the system adapts to the changing needs of the student. LEGATS uses a teaching format to lesson design that uses 'teach a rule', 'demonstrate it by example' and 'test the student' as teaching activities. LEGATS has added an additional component: 'provide feedback' - the answer to incorrect responses during the test. This feedback enhances the student's learning experience by letting the student learn from their previous errors. Kobsa *et al.* (1996) created an adaptive system to address comprehension problems experienced by students. The system presumes that students who bypass information do so because they are familiar with it, and students who request it want to acquire knowledge.

Yin *et al.* (2002) investigated the individual differences in the application of metacognitive strategies and suggested that a pre requisite knowledge of text structure could enable the student to more effectively observe and have greater control of strategies. This in turn helps the authors to determine what kind of structure to use to interrelate ideas. In most cases the use of hierarchical summaries, conceptual maps, advanced or thematic organisers is designed to raise the student's awareness of text structures (Harris, 1990) .

Shippey *et al.* (1996) created the *AlgoNet* system that organised information based on a learner's plan to use information. They incorporated cognitive media types such as definitions, examples, worked problems and problem sets. Part of this system is to incorporate questioning learning strategy in a way that it provides a list of questions that users can select to ask about a current topic. They expected that this question-based format would encourage students to ask questions of peers and instructors, as well as themselves.

The 'SHriMP' tool (Storey *et al.*, 1998) was devised to support a combination of comprehension strategies for programming professionals and effortlessly switch between them. Strategies represented in this application were bottom-up, top-down and knowledge based strategies. The authors suggest that *ShriMP* should enhance or ease the programmer's preferred strategies, rather than impose a fixed strategy that may not always be suitable.

Summary

This literature review explored the connection between cognitive psychology, performance within instructional hypermedia and application of effective learning strategies in hypermedia. The chapter builds on the work and the development of the hypermedia system that incorporated learning styles. The review has shown that learning strategies provide a good foundation for the development of an adaptive learning system. The chapter reviewed ways of incorporating a variety of learning strategies into adaptive hypermedia. Such a system should adapt to the knowledge and preferences of the student, by adapting the presentation of the interface and the learning strategy that 'works' within specific learning context. The system should support the student with the effective strategy and identify whether the strategy is not working and modify it. The next chapter will describe the architecture of an AHS that adapted two learning strategies within a hypermedia framework.

Chapter 8. ILASH: Architecture and design

8.1. Introduction

This chapter describes the main ideas behind the adaptation and architecture used in the educational hypermedia application called ILASH (Incorporating Learning Strategies in Hypermedia). The system presents the novel idea of incorporating learning strategies within adaptive hypermedia. The focus of adaptation in ILASH is to provide a representation of an appropriate strategy for students whilst learning. The chapter describes a computational framework designed to provide adaptive support for learning by using ILASH. The framework includes different adaptive techniques embedded within the user interfaces and a linking structure to scaffold and encourage the use of strategies. The framework also includes a dynamically updated student model.

The potential benefit of adapting a number of powerful learning strategies to enhance learning and performance prompted the integration of interactive studies to stimulate the strategy adaptation. The system ILASH contains courseware developed primarily for GCSE-level students. The courseware has been adapted from a book about AQA Physics level by Fullick (2001). The chapters chosen for the study contain scientific concepts, principles, and theories that are used to explain observations of the natural world. The first (adaptive) session of the system contains courseware on "The behaviour of waves", the second (non-adaptive) session contains courseware on "The Solar System". Each session contains the same number of pages, and the student's knowledge is assessed at the end of each lesson. As part of the system usage, the students browse the adaptive session first and then complete the post test, followed by a non adaptive session and second post-test. The post-tests contain the same number of questions, and they are tied to lesson objectives and three levels of Bloom's taxonomy (1956)[1]. The results of the post-tests between the adaptive and non-adaptive sessions are compared.

8.2. Implementation

ILASH is implemented in a web based environment, using the following technologies: the PHP scripting language, MySQL, a relational database engine, an Apache web server, HTML, XML (Extensible Markup language) and XSL (Extensible stylesheet language) technologies. PHP is a server side scripting language that can be embedded within HTML documents. This provides an easy way to incorporate dynamic content within what was previously a static document. Also, PHP is well suited for reading information from web forms and maintaining sessions between pages. This is important in order to keep the name of the currently authenticated student, their browsing actions and history in the student model. Sessions are used to maintain student-specific information. XML and XSL allow content to be separated from the presentation, where XML is used to store the content and XSL is used to present pages with different layouts.

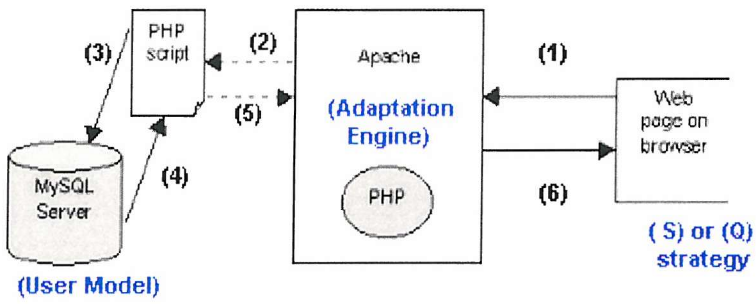


Figure 8.1. Architecture of the system

Figure 8.1 shows the system architecture. A student requests a particular page from the Web server by means of a Web browser (1). In response to this request the Web server calls a PHP script (2), which is executed by the PHP preprocessor

[1] According to Bloom's cognitive domain taxonomy 'knowledge' is defined as an ability to acquire, to identify, to recognize knowledge of facts, specifics and abstractions and to recall previously learned information. 'Comprehension' implies the ability for translation, interpretation, extrapolation of meaning of information and understanding of the facts. 'Synthesis' is defined as an ability to discriminate, distinguish, reintegrate and organise the information and the relationships into a meaningful whole.

(3), pulling data from the database (4). The results are processed by the rest of the PHP script (5) and turned into HTML, which is returned to the student's browser (6). The current implementation of the system is as shown in Figure 8.1 and uses an Apache server. The student model is stored in a MySQL database. The courseware is stored in XML files. The students need to use a browser capable of parsing XML and XSL. XML is an Internet empowered syntax providing standards to describe information. XML separates management of content description, presentation and access. Its descriptive scalability enables easy reuse of information, especially from an authoring perspective as well as better handling of information. No specific client-side software needs to be installed on the client's PC. The adaptive educational application ILASH consists of three main components:

1. The Domain Model
2. The Student Model
3. The Adaptive Model

Each component will be described in turn in the following sections.

8.2.1. The Domain Model

This model represents the content formatted by XML. Multiple representation of the same content can become available by using different XSL templates. XSL uses XML syntax to create template rules to transform documents into formatted objects. Furthermore, XSL sheets contain a set of rules, which specify how to format certain elements in the document, such as the size of titles, or the background colour of paragraphs. These rules can also alter the position or order of text fragments.

PHP code is used to provide the logic behind content presentation and system-user interaction. A MySQL database holds information about the users, their run time browsing history and other information such as the length of time spent browsing pages and other static information stored in the user model. PHP allows great utilisation of sessions, where the state of the user's actions can be recorded and checked to see if they match existing information and therefore providing dynamic page delivery.

Knowledge prerequisites modelling

The 'domain' model in ILASH is based around a cognitive model of a user and the strategy that the student will apply to achieve a set task. The tasks the students are asked to perform are in this case: to summarise the supplied information by identifying the correct statement and answering a question on the declarative knowledge. In each section a student reads content that introduces a set of cognitive tools that should assist in applying the appropriate learning strategy. The user model maintains an estimate of the student's knowledge state. The student model evolves based on the knowledge prerequisites and the student's interaction with the application. The knowledge state is an indication of what kind of learning strategy is proving to be beneficial to the student at a given point in time. Knowledge prerequisites have been preset by the content author. For each session (adaptive and non adaptive), there are five lessons contained within 45 pages. The students have to complete 75% of the lessons in order to proceed to the post test. This tests whether the student has read the pages and satisfied the knowledge prerequisites. The lessons can be formatted to scaffold either summarisation or questioning skills. The system uses the student's answer via a test after each lesson as a clear indication of the 'working' strategy choice. The students can apply multiple learning strategies to achieve a task, and their preferred learning strategy choice is not tested before the use of the system.

8.2.2. The Student Model

The student model is used to adapt the display characteristics of the interface and the appropriate learning strategy to the needs of the student. The student's interaction with the system is reflected immediately in the system and in the learning strategy selection. The knowledge the student has attained is collected through direct questioning methods. The student model is dynamically updated and triggers the system to select the most appropriate learning strategy for each lesson. The student model contains the following information: Student ID, individual browsing history (history of visited links, time spent on each page), learning strategy preference, the number of switches between the two strategies and students' knowledge level.

8.2.3. The Adaptive Model

The adaptive model is responsible for providing a mapping of content interaction to user preferences. The adaptation mechanism code is wrapped around the XML content. The adaptation is based on a set of knowledge prerequisites and the current working learning strategy, according to the student's knowledge state and the working strategy, a combination of adaptive techniques is applied. The algorithm in Figure 8.2 was used to determine the student model in relation to the student's knowledge:

```
For each of the lessons
If score after each lesson is correct
THEN
The Learning strategy is preferred by the student, keep on using pages with that preference
ELSE
The Learning strategy is NOT preferred, a different strategy is needed
ENDIF
```

Figure 8.2. Adaptation algorithm

Each page in the courseware contains a session file with code to track students' actions. The session is checked by looking in a database to see if the session passed on the links that students visited. Variables set at the top of each page are used to check if the page should be displayed and they are compared with the relevant details from the database. The student is redirected accordingly if they are not. Once the page has been visited, the database is updated with the URL of the page. An example of the header of each page is shown in Figure 8.3:

```
...<?php
$prreq=6;
$p_type="s";
$url="refraction.php";
include("../session.php");
include("pagelinks.php");
header("content-transfer-encoding:ascii");
<?XML version="1.0?>
<?XML-stylesheet type="text/XSL" href="s_type.XSL");
...
```

Figure 8.3. Example of a page header

8.2.4. Learning strategy representation

The basic structure of the page layout is that the pages are divided into two formats: S_type (corresponding to the "summarising strategy" and Q_type (corresponding to the "questioning" strategy). Three factors were viewed as essential and sufficient to design the layout of an environment conducive to studying: the learning strategy, the text and link presentation and the structural signals. The S_type pages have a top-down approach where the material is presented with key points summarised at the end of each page. The S_type page presentation provides contextual clues to help students gain the basic understanding of the information (by using headings, dividing text into small chunks etc.). The aim is to provide the students with some elements of a summarising strategy.

The Q-type pages have a question asked after each paragraph (which contains an explanation of a concept). Arburn and Bethel (1998) suggest that directing the attention to deliberate questioning activities may encourage students to confront misconceptions which they have grown comfortable with, so that when resolving their discrepancies, more meaningful learning may occur.

8.3. Adaptive features of the system

The system allows the student interface, the linking and the content structure to change according to the student's knowledge state. The student's recall and understanding of content is continuously checked and an appropriate strategy is selected. The adaptive techniques used in ILASH are adaptive presentation (adaptive content presentation) and adaptive navigation support[2] (adaptive annotation and hiding of links) in the table of contents and adaptive link ordering in the adaptive side bar (see Figures 8.4 and 8.5).

8.3.1. The adaptive presentation technique

For adaptive presentation, a set of pedagogical rules of knowledge prerequisites is created that determine which layout and which pages should be presented. These

[2] See Brusilovsky (1996) for the definition of the techniques.

rules also determine which 'additional information' should be presented along with a concept and which 'examples' should be shown. The students are prevented from jumping to pages for which they lack prerequisite knowledge. (The pages that describe concepts are divided into prerequisite concepts by the author). The case is similar for the additional material related to the concepts (such as 'examples', 'science people' sections, 'interesting facts', 'ideas' etc.). Some pages have examples of concepts associated with them and some do not. The percentage of completed material is also displayed in the table of contents.

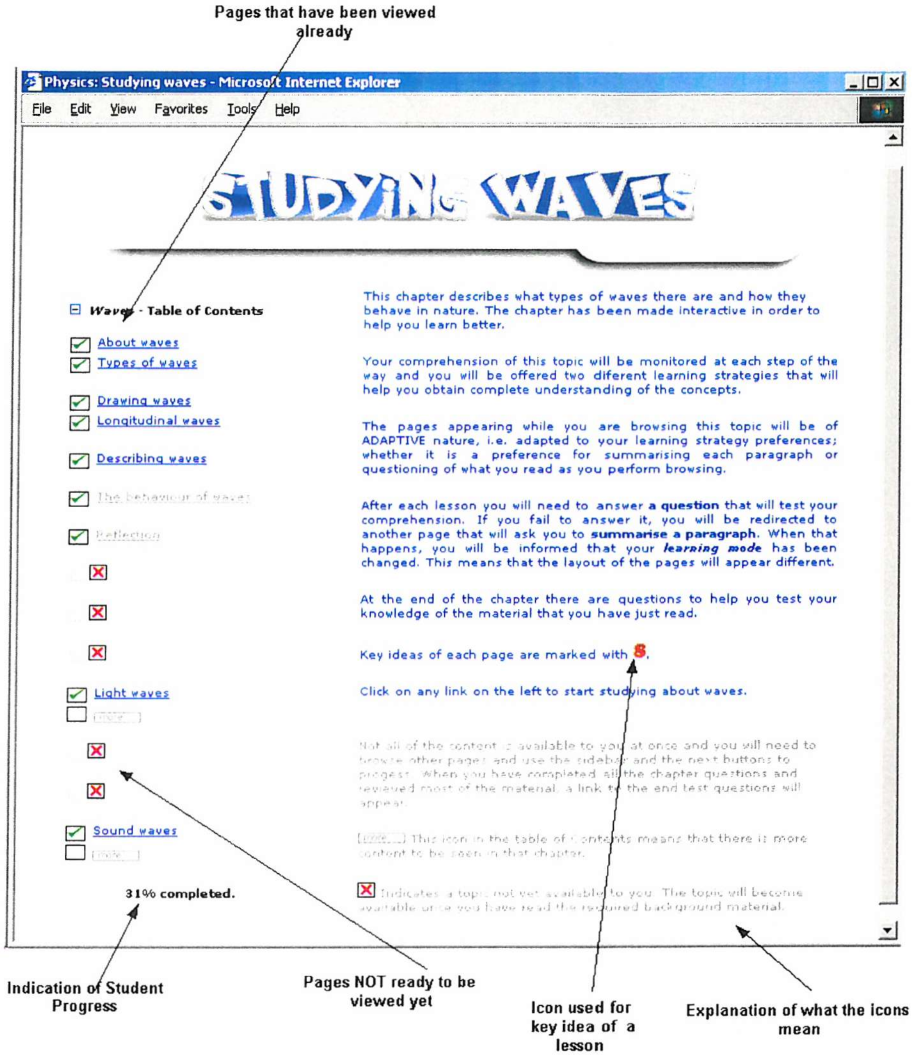


Figure 8.4. User interface with the adaptive table of contents

The system monitors the history of visited pages and supplies strategies at different points. The students are free to 'jump' between paragraphs. The technique follows a pattern of supplying different strategies adaptively, depending on the student's progress

8.3.2. The adaptive navigation support

For adaptive navigation support the system uses adaptive link annotation and adaptive hiding and ordering of links. The links to pages that the student is 'not ready to learn' become hidden and a 'cross' icon is placed next to them. The links to lessons that the student is ready to cover are displayed in the table of contents with a 'green tick' icon next to them.

Adaptive *annotation* is achieved by adding extra (textual or graphical) information about the links (such as adding green 'tick' and red 'cross' icons), or changing the colour of the links. (see Figure 8.4.)

Adaptive link hiding is achieved by hiding or not showing irrelevant links from the students, in the table of contents, where the links are shown or not shown based on the student's knowledge level. (see Figure 8.4.)

Adaptive link ordering (see Figure 8.5.) is achieved by using red colour for previously visited chapter, blue for current chapter links, green for a 'ready to learn' chapter. The order of links presented is determined by information contained within the user model. The links based in the green part of the side bar are judged to be the most appropriate for the user at that point in time.

In the adaptive version of the system, each page has the following links available in the adaptive sidebar:

- *Index*, takes the student to the table of contents page, providing an overview of the lessons
- *Search*, allows the student to find clarification for keywords
- *Examples*, takes the students to an example of a concept
- *Science people*, presenting more detailed information on the scientist mentioned in a lesson
- *Ideas and evidence,* presents the key points summarised for the concept
- *Back,* taking the students to the previous page
- *Next,* with a description on what the next page is about
- *Glossary* links, providing the students with definitions of terminology used in the content
- *Adaptive chapter links*: these links change in the adaptive part of the system to describe previously visited links, currently viewed links and next links available for viewing.

Previously viewed chapters, currently available pages and newly available links to chapters are presented in the adaptive side bar (see Figure 8.5).

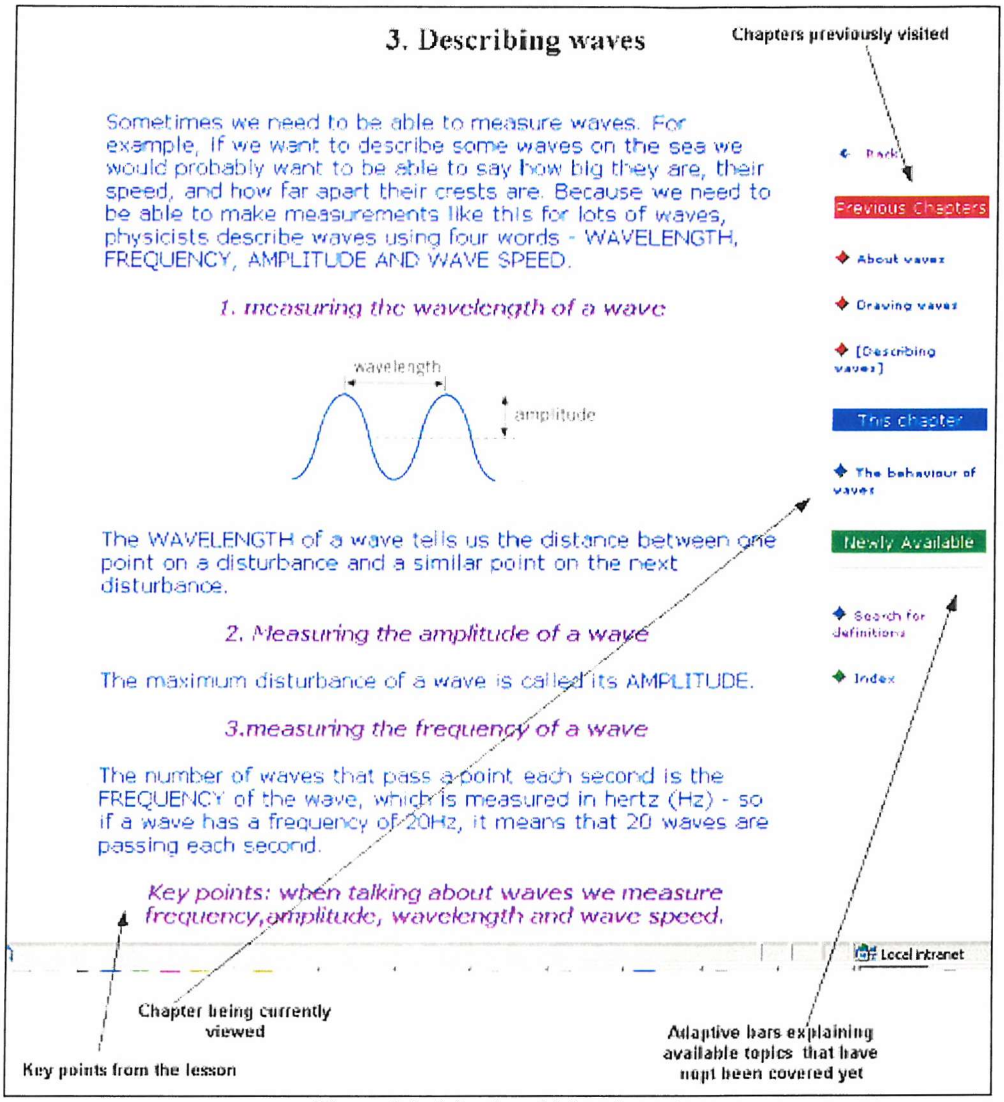


Figure 8.5. Adaptive sidebar layout

8.3.3. Linking mechanism implementation in ILASH

Two main types of links were implemented in ILASH. They were *structural* links, which define the structure of web pages and *referential* links, which are used to link to definitions of keywords within web pages. Examples of structural links applied within ILASH are the table of contents, and the 'next' and 'previous' links.

The structural links were implemented by using cascading style sheets (css files) and XSL documents; every document that was presented, shared a common style describing the presentation of the links and renders the display of links. These links were built manually and embedded within the documents. An example of using a cascading style sheet embedded inside an XML document is shown in Figure 8.6.

```
<STYLE>
    td {font-family:verdana,arial,helvetica; font-SIze:10px}
    a:hover {color:#6699ff; Text-Decoration: Underline}
    a:active {color:#6699ff; text-decoration: none}
    a:visited:unknown {color:#808080}
</STYLE>
```

Figure 8.6. Example of link annotation

On the other hand, examples of referential links include *glossary* links, *related information, further reading*, *keywords, examples* and *science people* links. These are essentially glossary links that relate a word in context to its definition. This type of links is useful to users as they conveniently fill in their missing prerequisite knowledge, without having to leave the current document. Referential links were annotated in purple colour in the adaptive toolbar (see Figure 8.5). Figure 8.7 depicts the way in which such links were embedded inside an XSL document.

```
<xsl:for-each select="TEXT">
 <xsl:apply-templates select="IMG" />
<xsl:for-each select="TEXTANDLINK">
<xsl:for-each select="TEXTBIT">
    <xsl:value-of/>
   </xsl:for-each>
   <xsl:apply-templates select="MYLINK" />
  </xsl:for-each>
<xsl:for-each select ="TEXTBIT">
   <xsl:value-of/>
  </xsl:for-each>
  </xsl:for-each>
```

Figure 8.7. Referential link inclusion in XSL format

The inclusion or exclusion of referential links within a document was decided using templates, such as the example shown in Figure 8.8.

```
<xsl:template match="MYLINK">
<a><xsl:attribute name="href">
<xsl:value-of select="href"/>
</xsl:attribute>
<xsl:value-of select="show"/></a>
</xsl:template>
```

Figure 8.8. Template describing whether a link should be hidden or not

Previously visited chapters or 'Back' links within ILASH made use of the JavaScript history function to provide access to 'recently visited link's via the *adaptive toolbar*.

Figure 8.9 depicts how the adaptive toolbar indicates those pages and links that have already been visited. Figure 8.10 contains an example of the embedding of 'back' and 'next' links inside php documents.

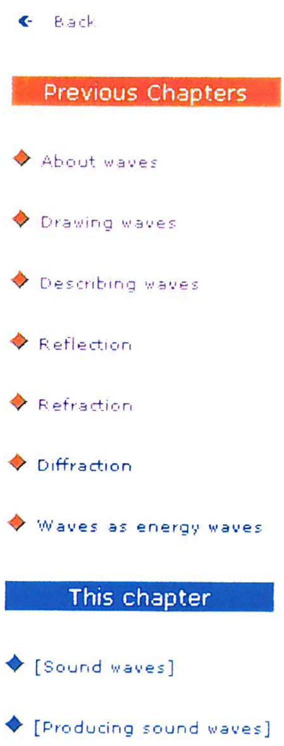


Figure 8.9. The links based on history

```
<NAVIGATEBACK>
    <MYLINK>
     <href>javascript:history.back();</href>
     <show>Previous page </show>
    </MYLINK>
</NAVIGATEBACK>
```

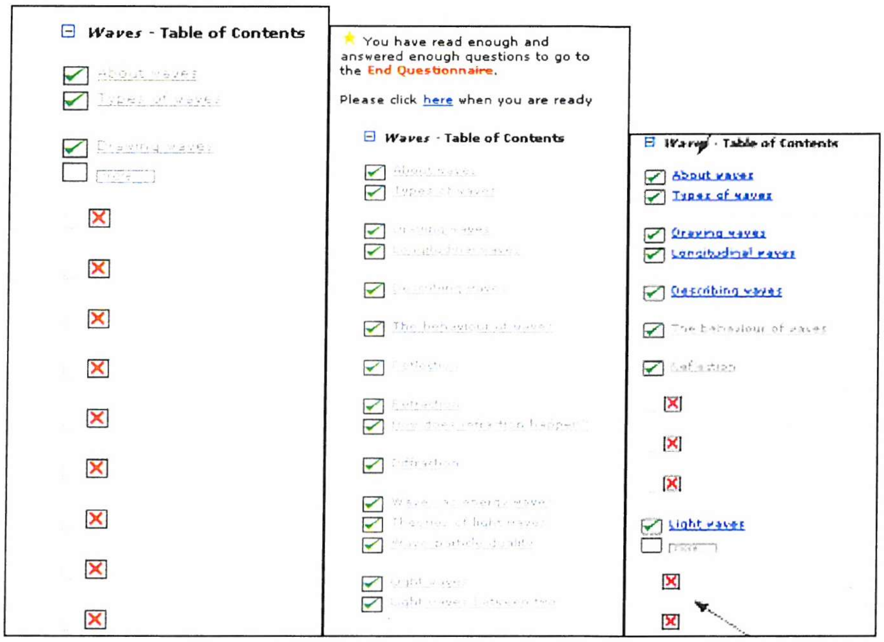
```
<MYLINK>
<href>energy_s3.php?session={$session}</href>
 <show>Next page</show>
</MYLINK>
```

Figure 8.10. The inclusion of 'Back' and 'Next' links in XML format

The links in the *adaptive table of contents* were annotated differently depending on the user' s level of knowledge. Figure 8.11 shows an excerpt from the logic used to show links in different annotations, while Figure 8.12 depicts the adaptive table of contents showing whether a link is accessible or not.

```
$completed=0; for($i=0; $i<12; $i++) {
  if($links_to_show[$plvl][$i] == 1) {echo "<hr noshade style='color:#cccccc;'
size='1'>"; $link_no = $page_offsets[$i]-1; $toggle=0;
    for($j=0; $j<count($links[$i+1]); $j+=2, $link_no++) {
      if((pow(2,$link_no) & $visited) == pow(2,$link_no) or ($i==0&&$j==1) or
($i>=$plvl && $j==0) or ($i==10 and $j>2)) {echo "$l1<a
href='".$links[$i+1][$j]."?session=$session'>".$links[$i+1][$j+1]."</a>$l2";
$completed++; } else { if($toggle++==0)
      echo "<img src='../../images/empty.gif' height=15 width=20 alt=''> ".
```

Figure 8. 11. Sample of code used in the adaptive table of contents for links



(a) (b) (c)

Figure 8. 12. Adaptive table of contents: (a) The links that students have yet to visit, have a red cross next to them to indicate the remainder of the lessons; (b) The links visited by the students are shown in grey colour (c) The links available to the student to visit are annotated in blue and have a green tick next to them; an icon showing 'more' indicate that there are few parts to the particular link.

Each document in ILASH is divided into parts such as heading, title, overview, introduction, summary, paragraph, links, info blocks, fact sheets and images. The link destinations of these elements are stored within each document (php file). Figure 8.13 presents sample script representing the links and other parts of each ILASH document (in XML format).

```
<?php
$number=6;
$url = "behaviour_of_waves_q.php";
include("../../session.php");
include("pagelinks.php");
header("Content-type: text/xml");
header("Content-Transfer-Encoding: ascii");
echo <<<END

<?xml version="1.0" ?>
<?xml-stylesheet type="text/xsl"  href="seq_q.xsl" ?>

<ADAPTIVEDOC>
 <LEARN>
  <INTRO>
   <NAME></NAME>
   <IMG>
    <src>../images/echo.gif</src>
    <alt>echo</alt>
   </IMG>
  </INTRO>

  <RELATED>
   <INFO>
    <href>javascript:history.back();</href>
    <show>Back</show>
   </INFO>
```

```
 </RELATED>

<INFOBLOCK>
   <TEXT>
    <TEXTANDLINK>
          <TEXTBIT></TEXTBIT>
          <MYLINK>
        <href>describe_q.php?session=$session</href>
           <show>How to describe waves...?</show>
          </MYLINK>
   </TEXTANDLINK>
           <TEXTBIT></TEXTBIT>
 </TEXT>
 </INFOBLOCK>
</LEARN>
</ADAPTIVEDOC>
END;
?>
```

Figure 8.13. Sample php document containing references to different parts of each page, such as intro, related info, paragraph, embedded images and referential links

ILASH captures actions performed by the students via the interactive process, such as answering the questions or summarising information. ILASH provides feedback and changes the availability of links according to student's selections. By embedding referential links inside the XML document and annotating links by using XSL templates, the required authoring effort was greatly reduced. The following case study describes student's interaction with ILASH envisaged by the author during both, adaptive and the non-adaptive sessions.

8.4. Typical scenarios

(1). Adaptive session

In this first, adaptive part of the system the students log in and start browsing. The students are not able to see all the pages at first. The links that the system provides become available as the student learns more. The students start browsing pages that embed "summarising" strategy elements (S_type page layout). At the end of a lesson a student is asked to summarise it ("summarising" strategy check) and if the student fails to provide a correct answer, then a different learning strategy ("questioning" strategy) is provided (the Q_type page layout). At the end of that lesson, when a strategy check point is reached, and if the student fails to answer, then the students can continue to browse the lesson, but the links to the pages they can browse are restricted until a concept is mastered. The post-test is presented after the students have completed 75% of studying.

(2). Non-adaptive session

This is the second part of the system where the students re-log in. This version of hypermedia courseware offers the students unrestricted navigation throughout the lessons (see Figure 8.14). The students can apply whatever learning strategy they wish. Summaries of key points are provided in the non–adaptive side bar. As with the adaptive session, the system tests each student's comprehension after each lesson by posing a series of questions. However, the strategy does not change and no clues are given if the students provide an incorrect answer. At the end of the chapter they take another post-test. The student's behaviour is monitored and the history of the visited links logged. Questions asked at the end of each adaptive or non-adaptive session follows Bloom's (1956) taxonomy of educational objectives on knowledge, comprehension and synthesis of information. The questions were created so that the students could demonstrate those cognitive levels, by having to define, match and classify information, as well as to describe and explain concepts in their own words.

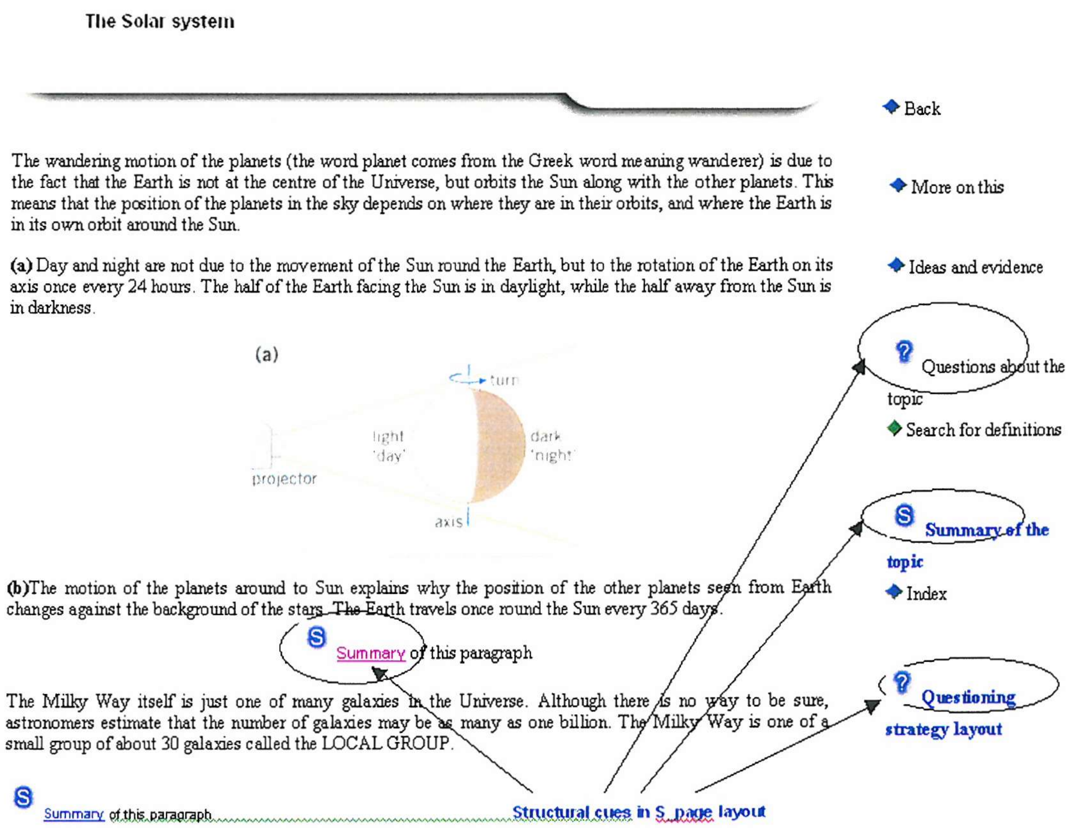


Figure 8.14. Non-adaptive page: S_layout

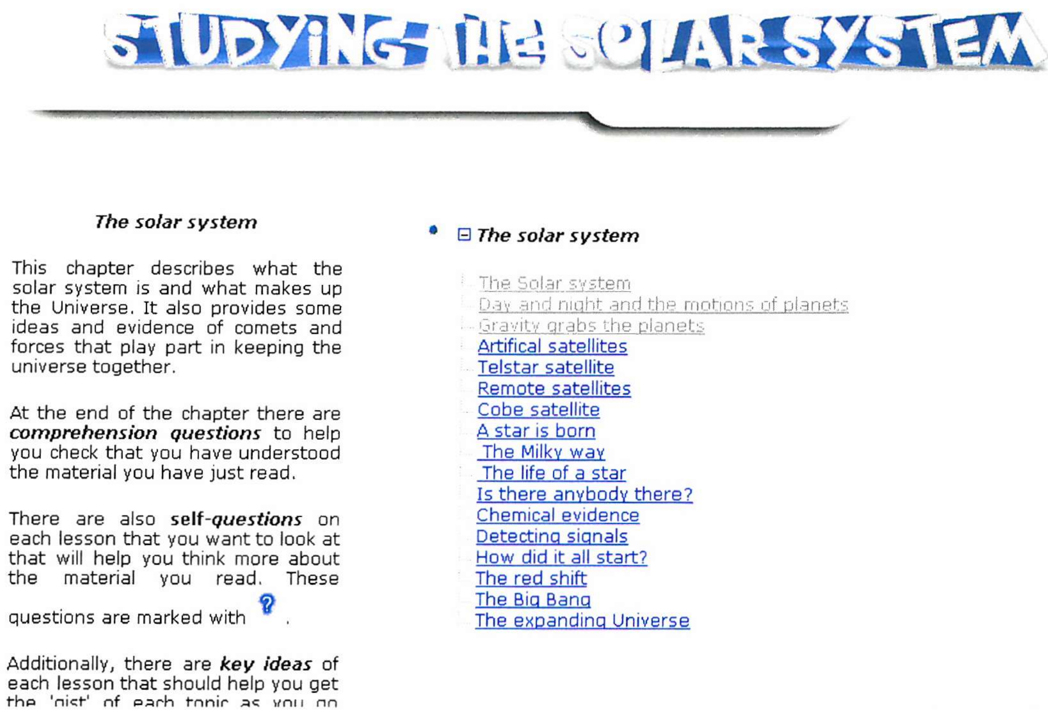


Figure 8.15. Non-adaptive table of contents with no adaptive annotation

Summary

In this section an adaptive hypermedia system has been described that provides the adaptation of learning strategies. This was achieved by applying adaptive presentation and navigational support. The system adaptively scaffolds the students and allows them to apply effective learning strategies. In terms of specific learning strategies, the study hopes to find significant improvement in a student's achievement following an adaptive lesson. The use of the aforementioned strategies may provide the students with the tools to enhance their success in hypermedia based studying.

The next chapter describes the formative and sumative evaluation of ILASH's features and the effects of learning strategy adaptation on a student's interaction with the system.

Chapter 9. Evaluating ILASH

9.1. Introduction

This chapter presents the results of the usability evaluation and the empirical-analysis of the experimental study relating to the student's interaction with the AES called ILASH and its effects on learning outcomes. The formative evaluation involved a usability study of the system. The empirical evaluation was intended to compare the post-test achievement score differences between adaptive and non-adaptive sessions of courseware. The chapter also evaluates the correlation between the increase in post-test achievement scores and the session browsing times.

9.2. Part I: Formative evaluation (usability study)

Formative evaluation evaluates the product before and during development. Formative evaluation creates qualitative (such as a list of problems encountered) data sets. The evaluation methods found in the literature revealed that most educational systems used a combination of evaluation techniques such as questionnaires, session logging and heuristic evaluation. The study was implemented in an experimental, real-world situation and it collected user interaction with the system.

Procedure

Two sets of trials were undertaken. The first time the system proved to be unreliable, and some immediate changes needed to be made before the students could proceed. Among the changes incorporated were the security of the system that needed improving. Additionally, some pages needed to be modified, as they contained the 'dead' hyperlinks that prevented the students from proceeding through the system. Once these serious usability issues were addressed, the second set of trial was undertaken. The students were informed how to commence using the system and their progress was monitored by the system. The implementer was available to answer any queries they had.

9.3. Evaluation methodology applied in the study

The main evaluation techniques employed in this research were the following:

1. Heuristic evaluation (included students and user interface designer reviews)
2. Attitude questionnaire
3. Session logging

All the techniques will be presented and the process of evaluation discussed in terms of what is questioned and what judgement are made. The comments made by the evaluators were returned via e:mail, as well as through attitude questionnaires. Attitude questionnaires tested the efficiency of the system, such as ease of accessing the site, ease of navigation, reliability of the system (i.e. the students do not experience problems or delays accessing material), absence of missing links or other link related problems, which mean that material is effectively cut off. There was no need for a content expert review, as the content was taken from the book written by a content expert. Logs of the students' progress were also made to compare the times the students spent on each session.

9.3.1. Heuristic evaluation

Heuristic evaluation is a popular and quick way to find problems with the usability of an interface. To do a 'heuristic evaluation' of a user interface we 'evaluate' how far the interface complies with a list of good design principles or 'heuristics'. As a result of this evaluation, the consistency of system was improved, which is particularly relevant to the adaptive part of the system. As part of the heuristic evaluation, one independent evaluator and five GCSE students were involved. The evaluator performed the test individually and he was asked to follow the list of heuristics. In all, he looked critically at the system, rationalized the good and bad aspects of the design choice and formulated potential improvements.

9.3.2. Expert opinion review

The following is the summary of some of the comments from the expert reviewer:

- Swap AP and NAP so that AP is presented first
- Modify Q_mode layout so that table of contents is on the left
- Improve security so that the students cannot browse the directory
- Incorporate existing learning style elements in the layout and structure of the courseware
- Test the pages on a PC with smaller monitor (800 x 600)
- Use more colours in the system
- Make better indications to the students of their progress through the system

The students were encouraged to report any issues they come across via e: mail. The complete list of all of their comments can be found in Appendix F. They provided very constructive comments in terms of system features and the page layouts as well as interaction modes.

9.3.3. Session Logging

The session logging is an integral part of the system and includes measuring the length of time that the students spend on each session. Details such as the pages visited, the length of time spent on each pages and whether they have completed the study were recorded. Another important feature of the session log was an indication of which session the students are browsing and whether they are online or offline. This type of logging is done automatically by the system, as the students browsed the courseware.

In summary, a combination of evaluation techniques was used and they contributed to a significant improvement of the system, ready for the empirical evaluation, which is described in the next section.

9.4. Part II: Quantitative evaluation of ILASH

This section presents in detail the results of analysis performed on the data collected in the second experiment. According to Castellan (1988) the most important element of evaluation is the evaluation of learning outcomes. "Knowing what the students learned from the application and how well they learned it, should be evidence of the effectiveness of the application". Part of this evaluation is to measure the difference in the students learning outcome and achievement depending on what type of learning session they use to learn.

9.4.1. Overview of the experiment

To examine whether adapting learning strategy to suit learning needs of each student within hypermedia courseware improves learning outcomes, an empirical evaluation was conducted. The students were asked to complete a number of browsing tasks. These tasks included the following: browsing, reading, searching for and memorising information displayed on the computer screen. At the end of each round of browsing tasks, the students would answer a series of questions to test their recall and comprehension of the supplied information. In this study the achievement scores from two post-tests and the length of browsing times between the two sessions were compared. Figure 9.1 details the flowchart of the experiment setup.

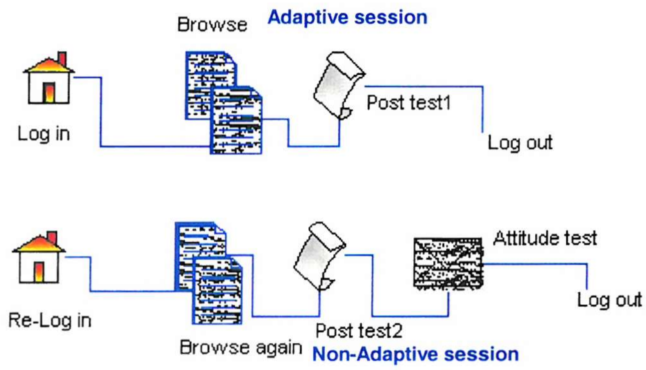


Figure 9.1: Flowchart of the experiment

The sample of the students reported in this study involved fifty-one GCSE students attending their second year of a two-year GCSE course. The experiment was conducted in two different schools. Coloma is a 'Girls only' (11-18) comprehensive school founded in 1869. Cornwallis is a large, non-selective 11-18 comprehensive school that gained Technology College status in 1994. 42 (82 %) of the students were from an all-girls college, while the remaining nine students (18 %) were from a Cornwallis college. The female/male ratio of the students was 43/8. Each student browsed through two different versions of web-based hypermedia courseware: the first version was adaptive and the second non-adaptive. The courseware lessons were adapted from a GCSE physics book

(Fullick, 2001, pp. 44-77). The material used for this online study was not covered in conventional lessons prior to the experiment. The first set of lessons described the behaviour of waves, while the second set described the solar system. The students were asked to carefully study all the available material. The experiment was conducted over the period of four weeks. The student could log out of the system at any point. The system incorporated the adaptation of summarising and questioning learning strategies.

9.4.2. Methodology applied in the study

At the start of the study, the students read a short explanation concerning the use of the system. They then logged onto the system and proceeded to browse and study the adaptive session. Having completed that, the students were presented with the post-test. The questions were knowledge and comprehension questions, as they tested recalling of facts, terms and concepts, synthesis of the information and analysis as suggested in Bloom's taxonomy (Bloom, 1956). The taxonomy provides a useful structure in which to categorise test questions that commonly occur in educational settings. It also divides the way people learn and includes three domains: the cognitive, psychometric and affective. The cognitive domain emphasise intellectual outcomes. The main categories of cognitive domain include the following: knowledge, comprehension, application, analysis, synthesis and evaluation. The learning outcomes in this study were tested on the knowledge and synthesis of information[1]. The adaptive browsing session was designed and structured in order to facilitate making connections between content and the learning process and allow for the application of summarising and questioning learning strategy processes to take place. The learning strategies were adapted according to a student's advancement through the system. In this session the participants were provided with adaptive features such as adaptive annotation and hiding of links combined with adaptive navigation support. The adaptive treatment that the students were exposed to, were the following three techniques:

[1] Knowledge is defined as exhibiting previously learned information by recalling facts, terms, basic concepts and answers. Synthesis is defined as 'building a structure or pattern from diverse elements and putting parts together to form a whole with emphasis on creating a new meaning'

1. *Adaptive navigation support (annotation and hiding of hyperlinks)*

Concepts were divided into chunks, and links to these concepts were divided into prerequisites. The colour and availability of links were related to the student's knowledge level. As the knowledge level increased, the greater number of links was available to the students. The links were annotated differently. The ones that the student was ready to learn were blue with a green tick symbol next to them, the ones that the student was not ready to learn were greyed out and a red cross symbol was next to them. Additional annotation of the links was available in the adaptive toolbar where the links that were clicked on already were annotated in red; the ones that the student is currently visiting are blue and the newly available ones in green colour. The ones that the student was not ready to learn simply were not there. When the student mastered all prerequisites for a concept, the link to this concept was made visible in the toolbar and the table of contents. The annotation of all links was computed by taking into account the students' knowledge level. Adaptive hiding was realised partially by hiding of the links that the students were not ready to learn yet. Simply put, the links that the students were not ready to view were not shown.

2. *Adaptive content presentation techniques (strategy adaptation)*

With this technique content appearance changes, and in this study the modifications was made by adapting the content of pages to represent 'learning strategy'. The adaptive representation of the 'summarising' (S_type) and 'questioning' (Q_type) learning strategies are described below:

S_Type – On an individual page, a summary of key ideas followed sections or topics relating a particular concept. On the following page, a series of related yet different summaries to the previous page content was listed. Only one of the concept summaries was accurate and the student was expected to pick the correct one.

Q_Type – On an individual page, a suitable question preceded every topic section. The questions were specifically related to the understanding of each topic. The questions posed were intended to stimulate and guide the students thought processes whilst digesting the concept. On the following page, a series of questions were posed to test the students' assimilation of the concept topic.

The intention was to encourage the students to apply the appropriate learning strategy (summarisation or questioning) by the provision of strategy clues (in this case key ideas and questions). Different kinds of thought processes were required while dealing those two different strategies.

3. *Adaptive curriculum sequencing*:

In this method the concepts were divided into prerequisites and the student's knowledge progress through the system was monitored. In some cases, if the student failed to complete a task correctly (whether it was to summarise information correctly or answer a question on the concept correctly), s(he) would be allowed to continue browsing without strategy change. In other cases, learning strategy would be changed immediately to adapt to the student' needs. This technique enforced the use of the two particular strategies adapted in the system. The questions asked after the lessons were also adapted from the book by Fullick (2001)

The students were not able to see all the pages at first. The links that the system provided become available as the student learns more. If the student was asked to summarise a lesson and the student failed to answer it correctly, then the strategy modification occurs i.e. a Q_type page (adaptive content presentation) is presented. If that fails, then the students can continue, but the links to the pages they can browse are restricted until the concept is mastered. The access to the post-test was presented after the students had completed 75 % of their studying. This level was decided by the author to ensure that the adaptive features that were available in the system were used sufficiently.

In the second, non-adaptive part of the study, the students logged in again, proceeded to browse and study the courseware with no adaptive features, combined with the full navigation freedom. This part offers the students unrestricted navigation throughout the lessons. The student's comprehension was tested after each lesson, but no clues were given if they provided an incorrect answer and no strategy change occurred. The students could still access the pages that provided the summary and questioning strategy (cues for using these two strategies were available). No adaptive annotation, link hiding or sequencing of content was available.

Upon the completion of the second session the students answered another post-test questions (6 questions). For the questions in the post-tests the students were required to express the answers in their own words and summarise concepts they had browsed. The students did not learn about either of the physics topics as part of the curriculum before using the system, so previous knowledge on either topic was not taken into account.

9.5. Hypotheses postulated in the study

This study sought to explore if there are significant differences in learning outcomes and comprehension for the students after they were exposed to an adaptive and non-adaptive learning environment. In significance testing, two hypotheses need to be formulated: the null hypothesis H_0 and the alternative one H_A. The hypotheses postulated for this study were the following:

- Null hypothesis for the test scores:

H_0: *Post-test score means for the adaptive session are not significantly higher than the post-test-score means for the nonadaptive session*

H_A: *Post-test score means for the adaptive session are significantly higher than the post-test-score means for the nonadaptive session*

- Null hypothesis for the browsing times:

H_0: *The browsing times for the adaptive and the non-adaptive sessions are not significantly different*

H_A: *The difference between browsing times for the adaptive and the non-adaptive sessions is statistically significant.*

9.6. Results interpretation: data collection and analysis

This section presents the performance results for the knowledge attainment and browsing times differences between adaptive and nonadaptive sessions. It also shows any dependency between the length of browsing times and the increase in scores achieved after browsing both sessions. The dependent variables for this study were the scores and the browsing times between two sessions. Fifty-one students completed the experiment. Data from an additional fourteen participants was discarded and not used in analysis due to unusable responses. The experiment was explained to the students verbally and again via the computer. Data was analysed using the 'Statistical Package for Social Science' SPSS v1.5 to check for statistical difference among different conditions in the study. For this particular study *t-test(or z test for n>30 students)* was applied to test if there was significant score gains between score-means. The *Wilcoxon rank* test was used to test the difference in lengths of browsing times between the two sessions. The *Pearson–rho* test was used to test the correlation between browsing times and increase in the score results. The *1-way ANOVA* test was used to check for significance between score gains and browsing times difference. Both sets of data for scores were normally distributed. Some additional findings regarding the use of links and adaptive features of the system are also presented. The appendices attached include the data collected for the students' scores and the lengths of browsing times for all the students for both sessions.

9.6.1. Difference between score means for adaptive and non-adaptive sessions

Examination of score data histograms indicated that the scores in both groups followed an approximately Normal distribution with no overt skew or outliers. Consequently, the two-sample, paired, two-tailed t-test was calculated to determine if the differences between mean variables (achievement scores) are significant. Although the hypothesis was directional in nature, the two-tailed test was used.

	Scores in adaptive session	Scores in non adaptive session
Mean (SD)	18.01 (5.98)	14.55 (5.85)

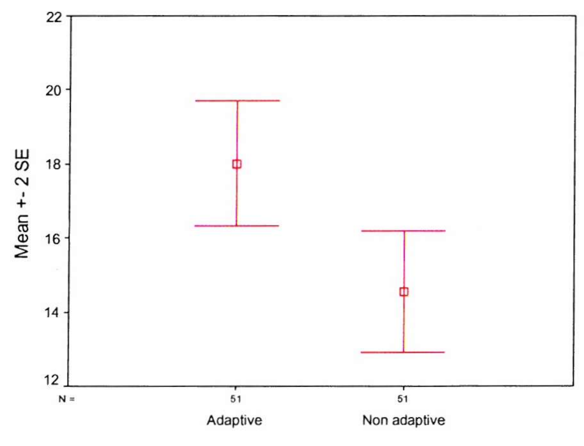
Table 9.1. Adaptive and non adaptive score statistics

Table 9.1 shows that the mean rating for adaptive scores 18.01 (SD=5.98), and the mean rating for non-adaptive scores is 14.55 (SD=5.85). The standard deviations for pre- and post-adaptive measurements reveal that the participants were slightly more variable with respect to the scores in the adaptive session.

Scores (Q1) in ADAPTIVE session - Score (Q2) in NON ADAPTIVE session					95% Confidence Interval of the Difference	
Mean (SD)	Std. Error Mean	t	df	Sig. (2-tailed)	Lower	Upper
3.46 (4.94)	.69	4.99	50	.000	2.07	4.85

Table 9.2. *t* test score results for adaptive and non-adaptive sessions

Table 9.2 presents the complete descriptive statistics concerning the scores of the students for both sessions. Analysis of the student performance indicates that the students achieved higher scores when studying the adaptive session compared with the nonadaptive session. From the post–test1 (after adaptive session) and post-test2 (after non-adaptive session), it has been found that there was a very significant difference of correctly answered questions ($t(50)=4.99$; $p=.001$, 2-tailed). The examination of group means in table 9.2 shows that the mean peak test score in the adaptive session was higher than the one obtained in the non-adaptive session. The level of significance for all analyses was set *a priori* at .05 level. The analysis indicates that there is statistically a very significant difference between means of scores. Since the significance value for change in scores is less than 0.05, we can infer that the average change in score points is not due to chance variation, and could be attributed to the learning strategy adaptation.



Mean scores for adaptive and non adaptive sessions

Figure 9.2. Scores after the post-questionnaires with mean values

Figure 9.2 depicts the mean value of scores (Q1) after adaptive session and the mean score value for nonadaptive session (Q2).

9.6.2. Difference between browsing times for adaptive and non-adaptive sessions

Examination of browsing times histograms indicated that the browsing times were skewed and outliers were present in both sessions. The 'Q_Q' plots have revealed that the browsing times distribution is not normal, and consequently the *Wilcoxon matched pair test* was used to test for a significant difference between browsing-times for adaptive and non-adaptive sessions. The completion times for browsing were measured from the start of each round till the students started answering post-tests.

	N (number of students)	Mean (mins) (SD)	Std. Error
T1 (browsing-times for adaptive session)	51	43.49 (23.69)	3.32
T2 (browsing-times for NON adaptive session)	51	27.33 (25.30)	3.54

Table 9.3. Browsing times mean values

Table 9.3 shows the mean rating for the browsing time in the adaptive session was 43.49 minutes (SD=23.69) and the mean rating for the browsing time in the NON adaptive session was 27.33 minutes (SD=25.30 minutes).

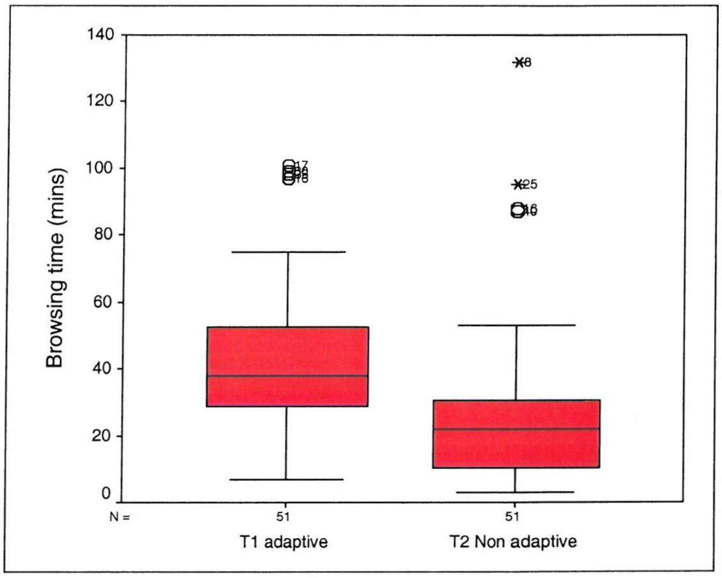


Figure 9.3. Browsing times for adaptive and non-adaptive sessions

The boxplot shows that browsing times for the adaptive session have greater variability. The Wilcoxon test was conducted to evaluate the hypothesis that there was a significant difference (reduction of the amount of time for the adaptive session) in the mean ratings between the browsing times for the two types of sessions.

9.6.3. The Wilcoxon matched pair test results for browsing times

When considering the browsing times it was expected that the students would spend less time browsing the adaptive session than the nonadaptive session. This test takes into account the sign of the sample differences by ranking the data, i.e. it considers both the sign of the difference and magnitude of the difference.

		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed
T2 - T1	Negative Ranks	42(T2 < T1)	26.39	1108.50	-4.18 **(a)**	.000
	Positive Ranks	9(T2 > T1)	24.17	217.50		
	Ties	0(T2 = T1)				
	Total	51				

(a)-Based on positive ranks.

Table 9.4. Wilcoxon matched pair test for browsing time ranks

The Wilcoxon test results from the Table 9.4 indicate that statistically there was a significant difference in the length of browsing times for the two sessions. At significance level α=.05, the value of critical, two-tailed z statistic is $z_{\alpha/2}=1.960$ and the value of critical, one-tailed $z_{\alpha}=1.645$ (*Source*: Common critical z score, Morse, 1993). The disposition of Ho in this case is determined by deciding on the following conditions: H_0 will be rejected in cases where ¦calculated z¦ >¦critical $\mathbf{z_{\alpha/2}}$¦, where calculated z < critical - $\mathbf{z_\alpha}$ and where calculated z > critical $\mathbf{z_\alpha}$ (Morse, 1993, p.596). In this case the second condition applies, i.e. because the calculated value of the test statistic is less than the critical value of z_{α}, where z (-4.18) <z_α (-1.645), we can reject the null hypothesis. The value of calculated z statistics, or the direction of the differences is negative. Hence the average time spent on the adaptive session was significantly longer than the time spent on the non-adaptive session.

9.6.4. Relationship between the length of browsing times and the percentage of the students

The following two tables present data describing the length of browsing time and the number of the students who spent different lengths of time and achieved different score gains. Out of 51 students 9 (~17.6%) spent more time on the non-adaptive session, while 42 students (~82.4%) spent more time on the adaptive session.

	Time difference	Number of students
	0- 5 mins	3
	5-30 mins	3
	30- 50 mins	2
	More than 60 mins	1
Average	33.50 mins	**Total: 9**

Table 9.5. Browsing times increase in the non-adaptive session

Out of 51 students, only 9 students spent more time on the non-adaptive session, with 33.5 mins on average.

	Time difference	Number of students
	0- 5 mins	3
	5-20 mins	17
	20- 40 mins	13
	40 -70 mins	9
Average	**29.44 mins**	**Total: 42**

Table 9.6. Browsing times increase in the adaptive session

Table 9.6 shows that the rest of the students (42) spent more time on the adaptive session, on average 29.44 mins. The results from the above two tables contradicts the expectation that the students would spend more time on the non-adaptive session. In summary, in less than one third of cases (9), the students spent a considerably longer time browsing the non-adaptive session (33.5mins on average), two thirds of them spent more time browsing the adaptive session (29.44 mins).

9.6.5. Correlation between browsing times for the two sessions

To test for the correlation between the lengths of browsing times between the two sessions, the non-parametric *Spearman rho* coefficient was calculated, as the browsing times do not follow a normal distribution.

Spearman's rho coefficient			**T1**	**T2**
	T1 (browsing times for adaptive session) vs. T2 (browsing time for non adaptive session)	Correlation Coefficient	1.000	.338(**)
		Sig. (1-tailed)	.	.008
		N	51	51

** Correlation is significant at the 0.01 level (1-tailed)

Table 9.7. Nonparametric correlations between browsing times for adaptive and non-adaptive sessions

Table 9.7 indicates that the correlation coefficient is 0.338, which implies a rather weak correlation between the browsing times between the two sessions. The two variables have a positive relationship, so as the browsing times for the adaptive session increased, so did the browsing time for non-adaptive session.

9.6.6. Relationship between the length of browsing times and the increase in scores for adaptive and nonadaptive sessions

The difference in browsing times between the two sessions and the difference in scores between the two sessions appear to be normally distributed. Table 9.8 shows that the mean value of the score difference is 3.46 with SD=4.94, and the mean value for the browsing time difference is 16.16 minutes, with rather large SD=30.96.

	Mean (SD)	N
Score difference (points)	3.46 (4.94)	51
Time difference (mins)	16.16 (30.96)	51

Table 9.8. Descriptive Statistics for means of score and time difference

To check for a correlation between the score differences and browsing times differences, Pearson correlation coefficient was used.

		Score difference	Time difference
Pearson Correlation	Score difference	1.000	.154
	Time difference	.154	1.000
Sig. (1-tailed)	Score difference	.	.140
	Time difference	.140	.

Table 9.9. Correlations between score gains and time difference

Table 9.9 presents negligible correlation between score gains and the amount of time spent browsing, $r=0.154$, $r^2=0.0237$ or 2.37% of change in score can be predicted from the difference in browsing times between two sessions. The correlation reported in the table is positive, although not significantly different from 0, which suggests that spending more time on the adaptive session and focusing their efforts on it, did not have an appreciable effect on scores.

To examine what effect browsing time difference made on the score gains, a variance analysis was computed, which showed no significant effect, F (1,50)=.838, p^2=.676 as shown in table 9.10.

Score difference	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	941.55	40	23.54	.838	.676
Within Groups	280.87	10	28.08		
Total	1222.42	50			

Table 9.10. The 1 way ANOVA results for score differences and time difference

9.6.7. Relationship between score gains and percentage of the students

Out of 51 students who completed the experiment, 75% of them obtained a score increase. Average score gain between two sessions for this number of the students was 5.98 points. More than one third of the students (37.25%) achieved score gains of 5 points or less.

	Score gains	Number of students (%)
	0-5 points	19 (37.25)
	5-10 points	17 (33.33)
	10-15 points	2 (3.92)
Total		**38 (74.51)**
Average	**5.98 points**	

Table 9.11. Score gains and percentage of students

Table 9.11 shows that one third of the students (33.33%) also achieved around average score gain (5-10 points), while a small percentage of the students (3.92%) achieved high score gains (more than 10 points difference) between the two sessions.

9.7. Other findings: effect of employing adaptive features on learning performance

Primary adaptive navigation support technique in ILASH was adaptive annotation and hiding of links achieved mainly through the presence of an adaptive toolbar and table of contents. The idea of having these techniques was to reduce cognitive load by hiding from the students the links that the system thinks they are not ready to learn. The technique is similar to the one employed in ISIS tutor (Brusilovsky and Pesin, 1994). The 'not- ready-to-learn' links were greyed out (hidden) and a red cross mark ☒ was drawn next to them. The 'ready-to-learn' links were coloured with blue and a green tick ✓ drawn next to them. Links to nodes within current lesson were annotated with the ⊞ and ⊟ icons, as shown in Figure 9.4.

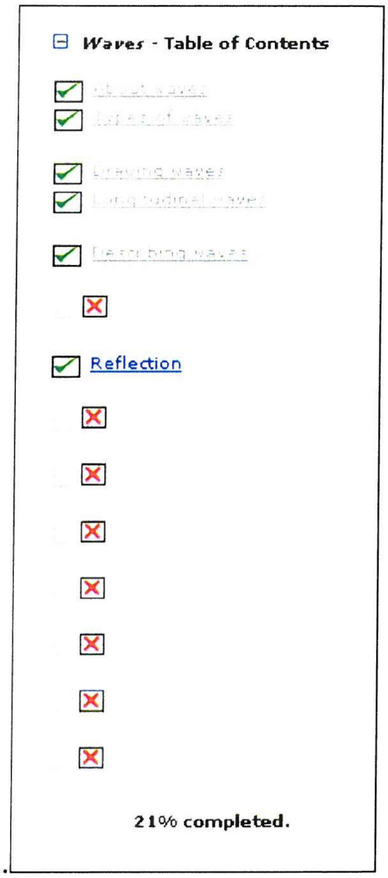


Figure 9.4. Adaptive table of contents with different annotation of links

Adaptive navigation support: the number of links clicked in both sessions

To examine the effect that the adaptive navigation support had on learning efficiency, the total number of distinctive and repeated links for both sessions was counted. The links available to the students were annotated and located in the toolbar on the right hand side of each page, as shown in Figure 9.5. The links that were available were coloured blue, the ones that have already been visited were coloured red and the ones that are recommended to be visited next are coloured green. This toolbar was intended to provide navigation support as the students browsed the pages. In addition, the student's progress was indicated at the bottom of the adaptive table of contents by numerical presentation of percentage of covered material. For further navigational support each 'Next' and 'Back' link had some textual description about the concept behind the link.

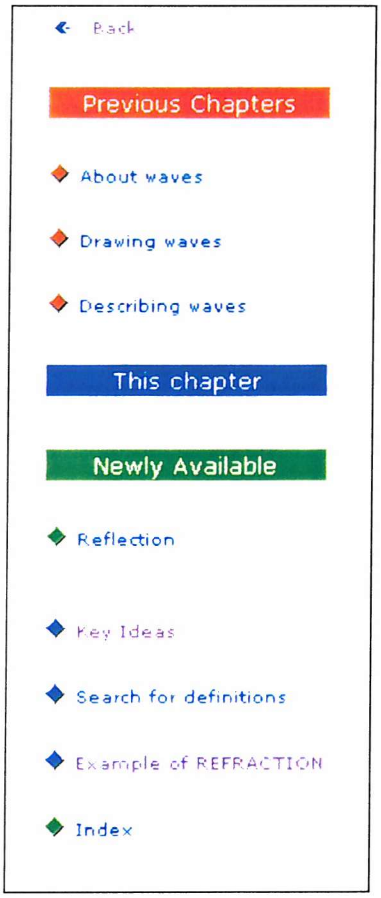


Figure 9.5. Adaptive toolbar with different annotation of links

Table 9.12 indicates that the total number of links clicked in the adaptive session was larger than in non-adaptive session. The number of repeated links in the adaptive session is much larger (10 times) than in the non-adaptive session.

	Total Number of distinctive links (adaptive session)	Total Number of links(non adaptive session)	Number of repeated steps in adaptive session	Number of repeated steps in non adaptive session
Total	2362	1537	4055	433
Mean	46.31	30.14	79.51	8.49

Table 9.12. Number of links clicked by the students in adaptive and non-adaptive sessions

Table 9.12 presents the mean and standard values of the difference between the number of clicked links for the two different sessions.

			Total Number of links (AS)	Total Number of links (NAS)
Spearman's rho coefficient	Total Number of links (AS)	Correlation Coefficient	1.000	-.012
		Sig. (2-tailed)	.	.932
		N	51	51
	Total Number of links (NAS)	Correlation Coefficient	-.012	1.000
		Sig. (2-tailed)	.932	.
		N	51	51

Table 9.13. Spearman rho correlations coefficient for the total number of links between sessions

Table 9.13. indicates a negligible negative correlation (r=-.012) between the total numbers of links between the two sessions. Consequently, the nonparametric Wilcoxon matched pair test was used to test the mean values of number of links between the two sessions.

Total Number of links (NAS) - Total Number of links (AS)	N	Z	Asymp. Sig. (2-talled
Negative Differences(a)	47	-5.88	.000
Positive Differences(b)	4		
Ties(c)	0		

(a) - Total Number of links (NAS) < Total Number of links (AS)
(b) - Total Number of links (NAS) > Total Number of links (AS)
(c) - Total Number of links (NAS) = Total Number of links (AS)

Table 9.14. Wilcoxon test for the number of links between two sessions

The results shown in Table 9.14 indicate a significant difference, z=-5.881, p=.000 (2-tailed). The total number of visited distinctive links in the adaptive session is higher than the total number of distinctive links in the non-adaptive session and therefore the z statistics or the direction of the differences appears to be negative. At significance level α=0.05 and confidence interval of 95%, for the two-tailed test, the looked up critical value of test statistics is $z_{\alpha/2}$=1.96 (*Source*: Morse, 1993). The calculated test statistics z is higher that the value of the critical z, *i.e.* z (5.88)>$z_{\alpha/2}$,(1.96). This suggests that the total number of links for the first session (adaptive) is significantly higher than the total number of links for the second (non-adaptive)session.

One of possible causes of this effect is the nature of adaptation in the first session, where adaptive sequencing was applied. This meant that the students needed to fulfil knowledge prerequisites before proceeding through the courseware. Another speculation would be that some students were not aware of the adaptive tools available to them and therefore made unnecessary step repetitions. Having scanned the logs of link history a pattern for some students emerged. As the students were allowed to log out and log back in as many times as they wished over the period of four weeks, every time they logged back in, it appears that they retraced numerous links. This is likely to have contributed to such a high number of repeatedly visited links.

9.8. Summary of the results

Alternative hypothesis H_{A1} was supported. Post-test score means for the adaptive session are significantly higher than the post-test-score means for a nonadaptive session

Alternative hypothesis H_{A2} was supported. The difference between browsing times for the adaptive and non-adaptive versions of the courseware is statistically significant. The value of z is negative, which indicates that a significant increase in browsing time in the adaptive session occurred, compared to the length of time spent on the nonadaptive session.

Table 9.15 presents a summary of all the results obtained as part of ILASH evaluation.

Means of scores between two sessions

Session type	Mean scores (SD)	t-test difference	Significance (2-tailed)
Adaptive (AS)	18.01 (5.98)	4.99	p<.000
Nonadaptive (NAS)	14.55 (5.85)		

Means of length of browsing times between two sessions

Session type	Mean times (mins)	z	Significance (2-tailed)
Adaptive (AS)	43.49 (23.69)	-4.18	p<.000
Nonadaptive (NAS)	27.33 (25.30)		

Correlation between browsing times for two sessions

Spearman's rho correlation coefficient	1.00	.338
Sig. (1-tailed)	.	.008
N	51	51

Correlation between score gains and time difference between two sessions

		Score difference	Time difference
Pearson Correlation	Score difference	1.00	.154
	Time difference	.154	1.00
Sig. (1-tailed)	Score difference	.	.140
	Time difference	.140	.

Correlations between total number of links between sessions

		Total Number of links (AS)	Total Number of links (NAS)
Total Number of links (AS) vs. Total Number of links (NAS)	**Spearman's rho** Correlation Coefficient	1.0	-.012
	Sig. (2-tailed)	.	.93
	N	51	51

Difference between means of the total number of links between two sessions

Total Number of links (NAS) - Total Number of links (AS)	N	z	Asymp. Sig. (2-tailed
Negative Differences (a)	47	-5.88	.000
Positive Differences (b)	4		
Ties (c)	0		

Table 9.15. Summary of the results obtained in the study for the mean values, standard deviation, t-test and significance levels

Discussion

The following discussion concerning the identified factors provides an insight into possible reasons for these findings. This was a study evaluating what impact the adaptation of learning-strategies within hypermedia has on learning outcomes. In the case of this study involving 51 GCSE students the main hypothesis postulated, regarding the mean scores difference, was found to be particularly pertinent.

In analysing the responses to the knowledge questions, it appears that the students benefited from adaptive courseware, as the results suggest that the students achieved significantly higher scores while browsing the session that adapted their learning strategies.

With regards to the browsing times between the two sessions, the evidence suggests that there is a statistically significant difference between the lengths of time the students spent on two sessions. On average, the time it took to browse the adaptive courseware was significantly longer than the time it took to browse the non-adaptive courseware.

The data analysed indicated that there was not a very strong correlation between the students' performances and browsing times, *i.e.* browsing times do not appear to affect the increase in scores after each session. The results indicating that the scores are not affected by the browsing time differences may seem surprising, but a closer examination shows that it is not unreasonable. The adaptive sequencing technique required the students to browse at least 75% of the content before proceeding to the post-test, while such a restriction was not imposed on the students in the non adaptive session. We can speculate that other factors, such as the students' reading speed, Ng *et al.*, (2002), motivational and time constraints might have affected the browsing times. The correlation coefficient indicated that only 10.75% of score difference is explained by the difference in browsing times.

Additional calculations were performed to test what effect the adaptivity integrated in the system, has on the learning performance. The results achieved by counting the total number of links followed by each student for both sessions indicate that on average the number of links visited by students was not reduced for the adaptive session. This may be due to the partially prescriptive nature of adaptation applied in the system (adaptive curriculum sequencing) and the adaptive navigation, where the students could not proceed through the courseware unless their knowledge and comprehension prerequisites were fulfilled. Overall, the adaptive session did not improve the students' efficiency, as the total number of distinctive links followed in the adaptive session versus the non-adaptive session was much larger.

The next section deals with the students' satisfaction with using ILASH. The students' opinions were collected through the attitude questionnaire posed at the end of their interaction with the system.

9.9. Students' satisfaction

After the students had used two variants of the system, they were asked to provide their viewpoints on various aspects of the adaptive part of the system. Subjective satisfaction was determined from the students' answers to a paper-and-pencil questionnaire. The questionnaire consisted of 5 sections with 24 questions and they could also add additional comments. All statements used the 5-point Likert scaling grading from "Strongly Agree", "Agree", "Neither", "Disagree" to "Strongly disagree". Forty-one students took part in the attitude questionnaire. The results are presented in the following tables and graphs. The attitude questionnaire can be found in Appendix F.

9.9.1. Presentation

Statements 1–5 measured the presentation of the information delivered in the adaptive part of the system. 70% of the students found the layout of the system clear, with only a small percentage of the students disagreeing (~2% or 5 students). Similar results were obtained for the structure of the courseware, (around 50% of students) and the change of layout from the summarising layout to the questioning layout (~54% or 22 students). A big majority of the students found the colouring used for visited and unvisited links appropriate (~66 % or 27 students).

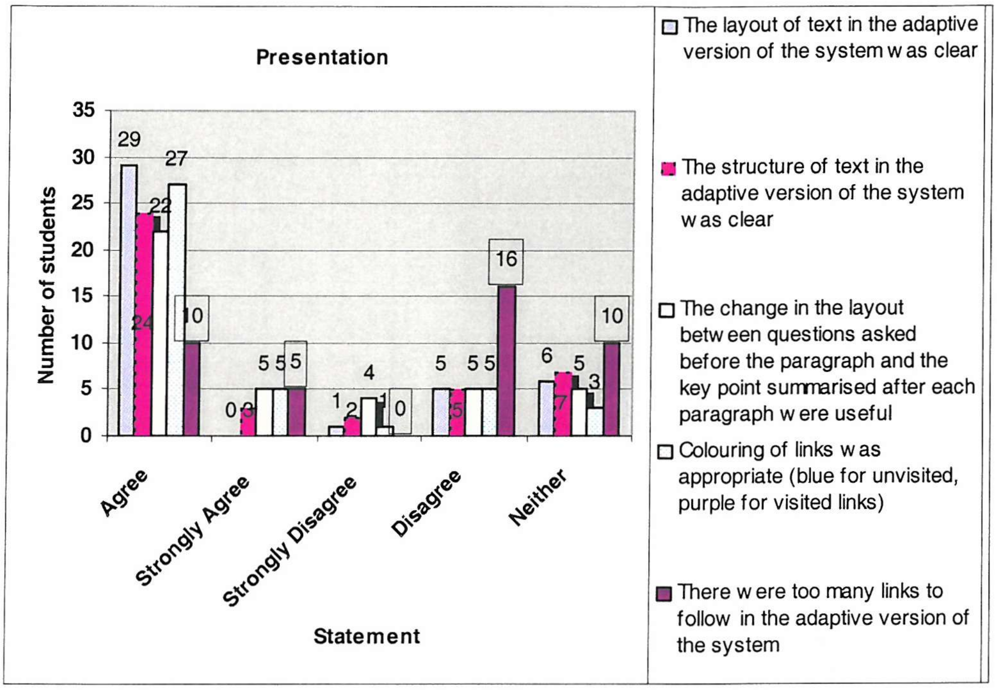


Figure 9.6. Students' opinions on the presentation features of the adaptive system

When asked if the number of links they needed to click in the adaptive part was too big, the spread of the students looks different, where only one quarter of them agreed that there were too many links, one quarter of them did not have particular preference, while 39% disagreed. We can infer from this last observation that the students did not find the system too overwhelming. Figure 9.6 summarises the spread of the students' opinions on the presentation part of the adaptive system.

9.9.2. Exploration and navigational freedom

Statements 6–8 of the attitude questionnaire measured the exploration and navigational freedom of the information delivered in the adaptive part of the system. Figure 9.7 summarises the students' opinions.

When asked about the adaptive versus the non-adaptive table-of-contents, a majority of the students (more than 60%) agreed that they preferred the adaptive one. Around 26% of the students did not have any particular preferences. It appears that more than one half of the students agreed that the adaptive version was well presented and easy to use. The opinion seems to be split on the clarity of learning objectives, where 39% of the students agreed and ~27% disagreed.

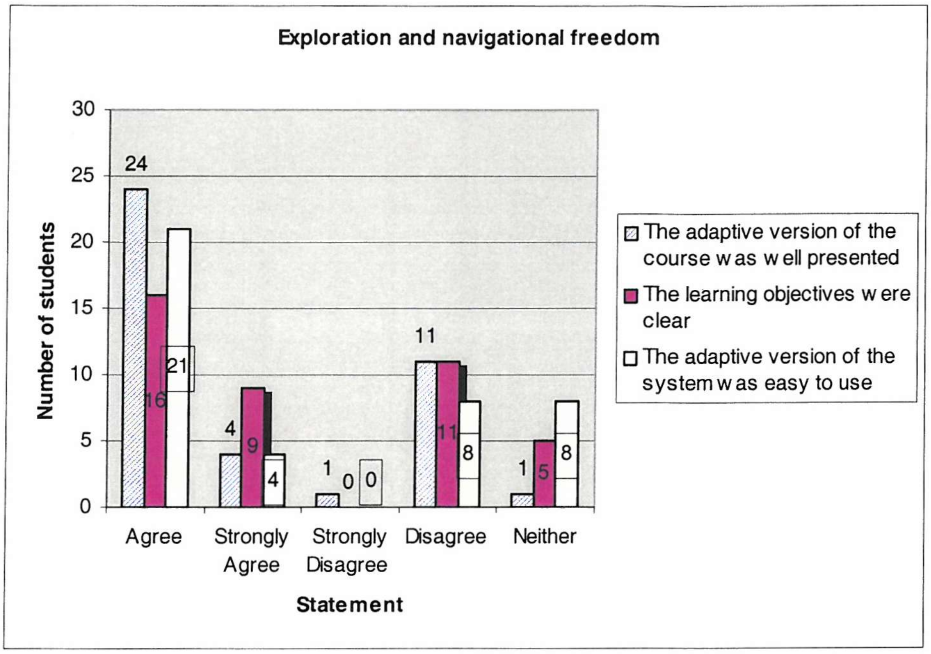


Figure 9.7. Students' satisfaction with ability to navigate and explore the system

9.9.3. Adaptive features of the system

Eight statements were set to test the students' satisfaction with the adaptive features of the system. Figure 9.8 summarises the students' opinions regarding the adaptive features of the system.

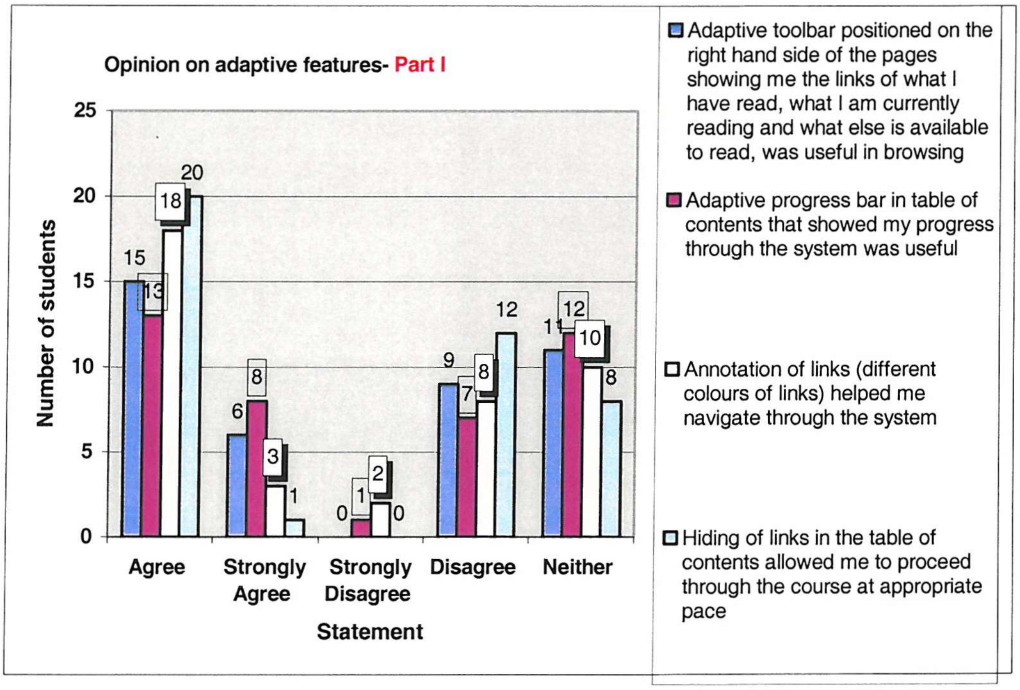
For the statement about the "Adaptive table of contents..." being useful, 15 students (~37%) in addition to 6 students (~15%) strongly agreed. 11 students did not have any preference and nine students disagreed with this statement.

For the statement about the "Adaptive progress bar..." being useful we have the following results: 12 (~30%) of the students did not have any preference, seven disagreed, one strongly disagreed, while 13 students agreed that it was useful (in addition to 8 (~20%) who strongly agreed). Figure 9.8 (Part I) summarises the above findings.

For the statement on the adaptive hiding of links, almost a half (~49% or 20 students) of the students agreed that it allowed them to proceed through the system at an appropriate pace. On the additional features of the system, that related partly to the learning strategy representation (strategy cues), such as the availability of key points of each paragraph, a very high proportion of the students (63% or 26 students) agreed that they were helpful. Additional 19% or 8 students strongly agreed with that statement too (see Figure 9.8, Part II).

For the second statement regarding the strategy-related-cue (having questions asked after each lesson) similar results were obtained. Again, a high proportion of the students 22 (~54%) students agreed that it helped them, while 11 (~27%) students strongly agreed with that. Only a small number of the students disagreed 2 (~5%) with this statement. From the results of the last two statements it can be inferred that that the majority of the students found that strategy-use cues helpful.

For the final two statements on the adaptive features of the system (see Figure 9.8, Part II), namely layout change (partial strategy representation), the students were divided in their opinion. 13 (40%) of the students agreed or strongly agreed (3) that "switching strategies..." was helpful. Quite large number of students 9 (~22%) combined with 8 students (~20%) who felt strongly about it, disagreed with that statement. A similar number of the students did not have any preference (8 students).



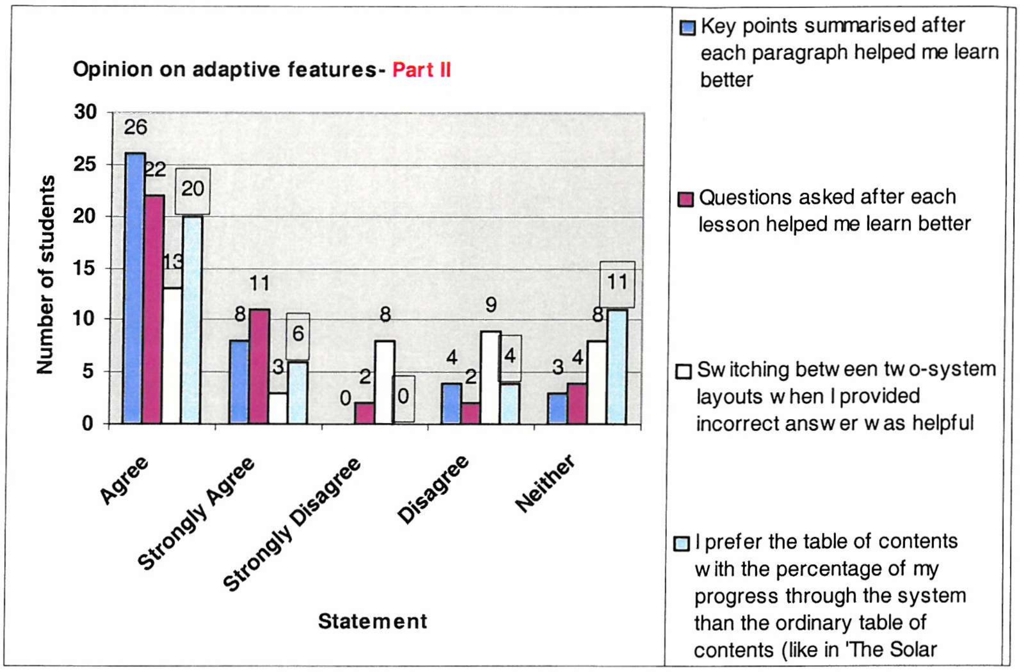


Figure 9.8. Students' opinion on adaptive feature of the system

Finally, the majority of the students preferred the adaptive table of contents that showed them the progress through the system 20 students agreed (with additional six who strongly agreed). Only four students disagreed with the statement. Additionally, 11 students did not have particular preferences with regards to the adaptive table of contents.

9.9.4. SUMI assessment results

Five statements of the attitude questionnaire served for SUMI[2] assessment of the system. Figure 9.9 summarises the findings.

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2 A usability profile in terms of five usability scales. These scales indicate how users perceive a web site in terms of: Affect, Efficiency, Learnability, Helpfulness and Control. **Affect**: degree to which users like the site, whether they find the site pleasant to use. **Efficiency**: degree to which users feel that the site has the information they are looking for, that it works at a reasonable speed and is adapted to their browser. **Learnability:** degree to which users feel they can get to use the site if they come into it for the first time, and the degree to which they feel they can learn to use other facilities or access other information once they have started using it. **Helpfulness**: degree to which users feel that the site enables them to solve their problems with finding information and navigating. **Control:** degree to which users feel 'in charge', whether the site allows them to navigate through it with ease, and whether the site communicates with them about what it is doing (Kirakowski, 1993). http://www.ucc.ie/hfrg/questionnaires/sumi

AFFECT: Almost 49% of the students disagreed that the system was overwhelming to use, and only one sixth found it overwhelming.

EFFICIENCY: The results obtained for the system's efficiency show a somewhat different picture, where around 44% students actually did not think that the system allowed them to complete browsing the courseware in a timely fashion. This can be attributed possibly to the fact that the students needed to complete a quite high percentage (75%) of courseware before proceeding to the post-tests. The tests themselves might have been perceived as time-consuming.
The minimum time for the completion of the post-test was designed to be 20 minutes. This could also possibly be due to the sheer amount of information that needed to be consumed in a reasonably short period of time.

LEARNABILITY: Regarding learnability, it appears that a high percentage of the students (~61%, or 25 students) found it easy to become familiar with the system. Only a small number of the students (6) disagreed with this statement.

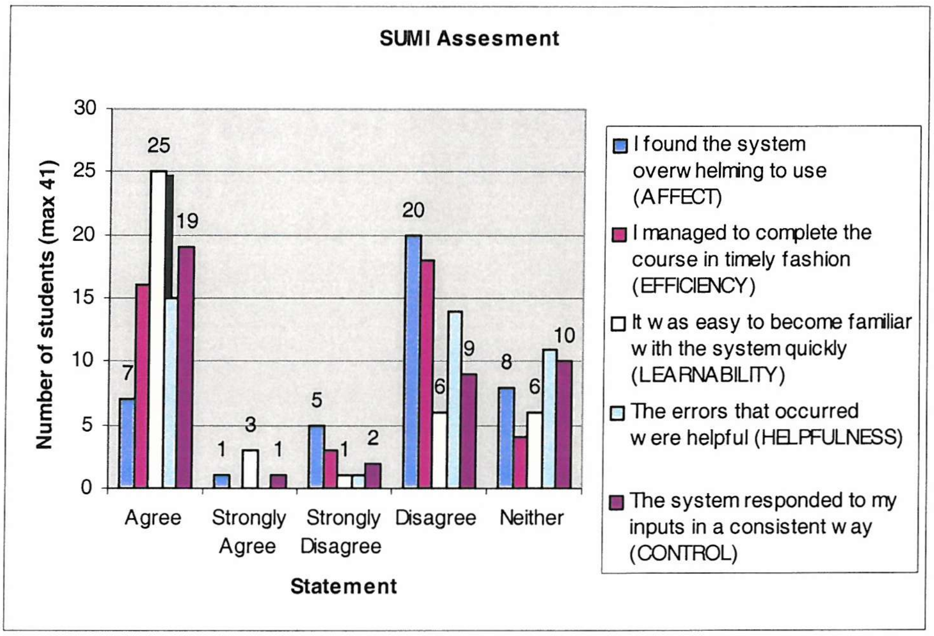


Figure 9.9. Results of SUMI assessment of the system

HELPFULNESS: The students were split on the statement of system's helpfulness. 15 students found the error messages that appeared on the screen helpful, while similar number found that they were not helpful (14). This dissatisfaction can be possibly attributed to the fact that while the students were using the system, the school had a very slow Internet connection, and some students had to keep refreshing the pages in order to continue learning. In such a situation no error messages were displayed on the screens, which students did not find helpful.

CONTROL: Finally, less that one quarter of the students found that system did not respond to their inputs in a consistent way, while a much higher proportion found that it did (19).

9.9.5. Overall impressions of the system

Three statements were created to examine the students' overall satisfaction with the adaptive part of the system. Figure 9.10 summarises students' opinions.

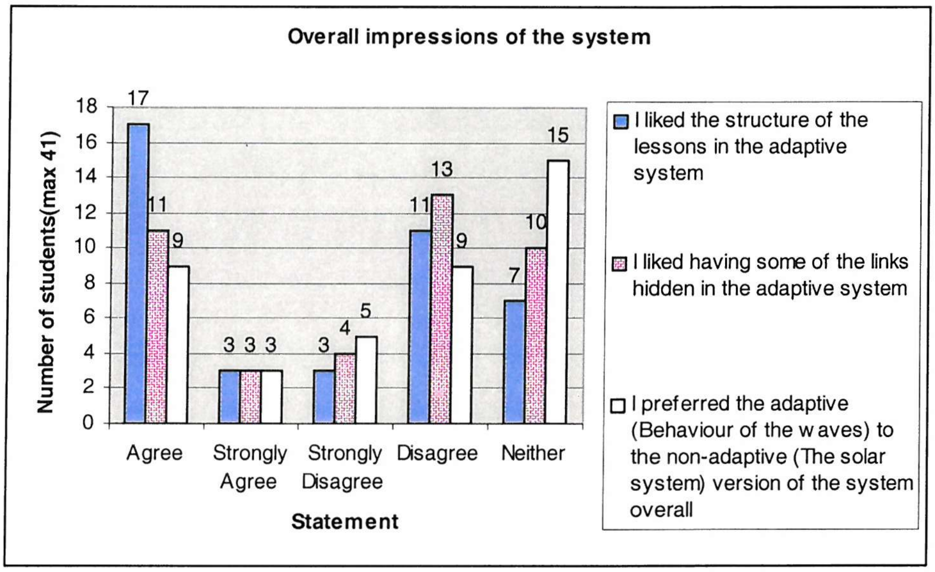


Figure 9.10. Students' overall impressions of the system

Figure 9.10 shows that when asked if they liked the lessons' structure, the majority of the students agreed (20), while 14 disagreed and seven students did not have any particular preference. Regarding adaptive hiding, the students were split in their opinion: (14) of students agreed and the majority (17) of students disagreed. 10 students or almost one quarter did not have any particular preferences.

Finally, when asked which version of the system they preferred to use, more students (14) preferred the non-adaptive version of the system, compared to 12 who preferred the adaptive version. Quite a large number of the students (15) did not have any particular preference for the system.

We may speculate that one of the possible reasons why a few more students preferred the non-adaptive version is the control element of the system. In the adaptive system the students could not navigate as freely and could not proceed through the system as much as they could have done in the non-adaptive version. This ties well with the difference in the amount of time they spent on browsing in the two versions of the system. From the browsing logs it appears that the time spent in the non-adaptive version was greatly reduced.

9.10. Summary and discussion

This was the second part of a study evaluating what impact the adaptation of learning-strategies within hypermedia has on learning outcomes. In the case of this study involving 51 GCSE students, the main hypothesis postulated, regarding the mean scores difference, was found to be particularly pertinent. The results from the data gathered suggest that the students benefited from the learning strategies being adapted to suit their needs.

The results have indicated that the adaptive techniques employed in the study do not necessarily reduce cognitive load or reduce the number of steps while browsing, but did improve the comprehension of material. The experiment revealed no strong relationship between score gains and the amount of time spent on the two sessions. It would appear that when integrating adaptive methods in learning environments certain techniques can enforce preferred learning strategies. The students should be assisted in selecting the most appropriate strategy for a given task through the adaptive methods available. The highly significant results achieved by the students are seen as providing a good indication that it would be worthwhile to proceed the adaptation of other learning strategies.

The data collected after this experiment was of a qualitative nature. The adaptive features that the students found helpful in contributing to their learning were the navigational support features employed in the system, such as the adaptive table-of-contents and the adaptive link annotation (see Figure 9.8, part I). It appears that the students liked neither the adaptive hiding (see Figure 9.10) nor the adaptive navigational toolbar (see Figure 9.8, part I).

Similarly positive results were obtained for the adaptive presentation elements, such as the summary of key points and questions being asked before and after each lesson. However, the other strategy-adaptation feature, such as the actual switch between strategies was not so equally well received. In addition, the features that the students did not find helpful were the relatively large number of links, the volume of information for each lesson and the time it took to complete the adaptive version of the system.

An interesting finding was that less than one third (15) of the students did not have any particular preference towards the adaptive and non-adaptive versions of the system. Less than one third (12) of the students preferred the version that adapted their learning strategy. Similarly, slightly more than one third (14) of the students preferred the non-adaptive version. The students felt comfortable with the adaptive version of the system but did not consider that it played an important role in aiding learning. Most of the attitude questionnaire comments were favourable. The participants commented on the consistent layout of the system from page to page. The study suggests overall that adapting learning strategies can make a positive difference in the student's learning performance and subjective satisfaction.

The tailored hypermedia system produced included only two of the many strategies that students can use while learning. The results of the experiment indicate that scaffolding and embedding learning strategies, via a combination of adaptive methods, can increase learning outcomes. However, the experiment was limited in terms of scope. Students can use multiple strategies to achieve learning and incorporating the adaptation of additional learning strategies could potentially contribute to learning even more. There are many variables in this survey that deserve much greater exploration, such as the possible correlation between the students' beliefs on learning strategies (metacognitive strategies) and the adaptation of learning strategies.

The following (final) chapter contains a summary and a review of the research conducted in this thesis. Following the review, the key issues raised by the research are discussed. The chapter is concluded with suggestions of possible directions for future work and application enhancement.

Chapter 10: Conclusions and future work

10.1. Introduction

This conclusion summarises the main findings of the thesis, starting with a historical overview and followed by a discussion of the short–term challenges facing the creation of adaptive educational systems.

10.2. Summary of the thesis

This thesis made an attempt to shine a light on the development of AES throughout history, starting from the original computer based educational systems through to the most recent ones that take into account a variety of learner differences. The AESs developed in the last decade are based on the formation of the essential elements of an adaptive hypermedia system. Many also adapt to basic user preferences, such as knowledge state (by placing users in stereotypical groups and distinguishing between novice and expert computer users). Very few systems branched out to use different kinds of adaptation to make learning via web-based courseware more effective. The adaptation presented in this thesis proposed a variety of ways of catering for individual differences, and provided a good foundation for building future adaptive hypermedia systems, where learners' needs are matched with their preferred learning style and strategy. This was demonstrated with the successful development of two adaptive systems: LSAS and ILASH. The study examined the relationship between the adaptive application of learning styles and strategies, whilst learning in a web-based hypermedia environment.

The research conducted in the study has attempted to address the mismatch found in traditional systems, between the students' learning preferences and hypermedia learning environments. Inherent in the implementation of hypermedia is an expert-defined structure, in which experts attempt to emulate direct parallels between structuring hypermedia and knowledge representation, "where knowledge is represented as a semantic network of concepts" (Pask and Scott, 1972). The research in this study employed a cognitive approach to designing hypermedia by matching and adaptively scaffolding students' learning preferences.

A recent expansion of adaptive systems that incorporate cognitive/learning styles (Carver *et al*, 1996; Triantafillou *et al*, 2002) and learning strategies (Bull, 2000) may begin to fulfil the demand for critical research about hypermedia learners and their practices while browsing hypermedia material. Learner differences, such as a preference for information processing, deserve to be recognised in the field of adaptive hypermedia education. The overall perspective gained from reviewing the various AESs is that there is considerable need for research regarding the embedding and adaptation of representations of learning preferences and their relationship to learning performance in hypermedia environments.

At the centre of the research into learning styles, two bipolar learning style differences, global and sequential, were incorporated into a single system. The characteristics of learners with these preferences were described in chapter three. The theoretical background for the representation of these two learning styles was also presented in the same chapter. Matching and mismatching conditions were set up for a group of learners. The initial adaptive system LSAS, built for the purpose of the research, aimed to classify the students into two stereotypical profiles and then provide individual scaffolding on the basis of browsing history of a student. The hypothesis postulated in this thesis is that learners who are assigned to a treatment that matches their learning style and which also provides adaptive support are expected to perform better than learning from the non-adaptive treatment. This has been supported by the evidence gained from the trial reported in Chapter 5.

Building on the work regarding learning preferences, a second system that recommended and represented two learning strategies was developed. The AES designed for the second part of the study succeeded in supporting a similar performance increase via the application of what are termed 'complex' learning strategies (Weinstein and Mayer, 1986), *i.e.*, strategies that require students to be actively involved in the learning process. The adaptive treatments were constructed based on the theoretical work applied in the area of text comprehension in the past 20 years.

The development of an application that incorporated learning strategies has demonstrated that hypermedia can be used to assist in catering for a variety of learning preferences. The approach taken to embed only a small selection of learning preferences proved to be effective. The system, called ILASH, was implemented, tested and its usability evaluated. The ILASH system was evaluated to test whether the difference in learning under two different conditions were statistically different. In one variant of the system, the application of students' learning strategies was supported adaptively, and in another variant, the students' learning strategies were not supported adaptively. The chief measure used in the evaluation was the student's ability to acquire, comprehend and synthesise (Bloom, 1956) information from within the adaptive and non-adaptive variants of the system. In terms of test scores achieved by the students, the students scored on average higher in the adaptive version than the non-adaptive version.

10.3. Limitations of the studies presented in this research

There were some limitations to the experiments conducted for this research.

Firstly, the narrow perspective of embedding only a small number of learning styles and strategies, thus limiting the range of learning preferences that the students may use. However, the study was intended to demonstrate how the adaptivity incorporated in hypermedia could be helpful to students and by incorporating only a small number of styles, the number of additional variables that could affect the results were limited.

Secondly, the length of evaluation in the first (LSAS) experiment may be perceived to be too short. It would be interesting to scale up the evaluation to cover prolonged use over a series of weeks or months.

Thirdly, this work did not take into account the students' metacognitive strategies, *i.e.* checking if being aware of the strategies that make them more efficient, learners may have been detrimental to the students' satisfaction with the system.

10.4. Novel research in this thesis

The contribution of this work to the field of adaptive hypermedia can be summarised through the following statements:

- A new methodology for designing adaptive educational hypermedia materials has been developed, which addresses a variety of different learning styles.
- An adaptive hypermedia application was developed, which implements both global and sequential learning styles.
- A novel method of adaptation was created by applying and embedding learning strategies in non–adaptive hypermedia environments

10.5. Suggestions on future research and enhancements

While the adaptive systems presented as part of this research provide many features that contribute to more effective learning, they stand to benefit even further from continuing improvements. The possibilities for extending the work can be summarised as follows.

Two major areas in which this work can be improved upon are the number of components modeled and the accuracy of the models that accompany each of them. The first adaptive system in this study tailored hypermedia content to only a very narrow selection of learning styles, which were selected based on the belief that they are some of the most influential styles that students could exhibit in hypermedia learning. However, students are likely to posses a multitude of learning preferences, so catering for a combination of learning styles and strategies could improve learning performance even more.

Furthermore, it would possibly also be beneficial to give users the ability to switch between modes and modify their preferences, therefore giving them more control over their learning style representation.

To ensure that adaptive educational systems are used on a wider basis, such complex systems should allow for the content to be more modular, so that teachers can 'plug in' different types of lessons. This would possibly be most beneficial in secondary education, in schools where web-based educational material is already available.

Another direction of research might be to examine students' beliefs on learning styles and their relationship to the interaction with learning materials.

Subsequently, the second adaptive system (ILASH) created as part of this study, could enable the provision of additional multimedia tools and cognitive cues, which aid learning in that environment and make the learning experience more interactive and interesting. Similarly, the second system should cater for additional cognitive learning strategies, such as note taking, highlighting, analysing, clarifying and the evaluation of one's own performance (comprehension monitoring).

Further studies should be focused on examining students' metacognitive skills before the use of adaptive environments. This way the designers of adaptive systems can ensure that students are aware of a variety of strategies that can be offered to the students to assist them in the learning process. This might influence the decisions that students make while learning and what metacognitive and self-regulating learning strategies (SRLS) they employ.

The second part of this study, which examined the adaptation of cognitive strategies, could be combined with the study of metacognitive strategies to check how students in the high and the low SRLS learn. The students' preference of learning strategies could be checked beforehand to examine their beliefs about what learning strategies they find beneficial.

Additionally, tools can be embedded within the adaptive systems to encourage students to build a wider repertoire of learning strategies. Riding and Ryner (2002) draw attention to the encouragement of widening such a repertoire.

Finally, a longer-term evaluation of both systems could be conducted. It would be interesting to see how the long-term empirical evaluation of the adaptive systems would scale up. One issue with the evaluation of adaptive educational systems is that it takes time. However, by trying to assess the usability, satisfaction and effectiveness of AES and conducting evaluation by using numerous lessons, this may provide a more realistic picture of the usefulness of AES in question.

10.6. Discussion and wider implications of the results obtained

There are several potentially important implications of the research presented in this thesis.

Although time consuming, studies of this nature are valuable. Criteria used for evaluation of adaptive systems are not generally agreed. Nevertheless, the study presented here represents a very small proportion of the evaluation research papers that examine learning gains using such complex systems (compared to say 'an ordinary' hypermedia system). The results of both types of evaluation revealed some of the possible benefits of incorporating learning preferences in adaptive hypermedia.

In general, the little empirical research evidence of AES shows that the use of adaptive software as learning systems may not necessarily lead to improved performance. The research should strive to 'appropriately' tailor the hypermedia courseware to the learners, whether it is in balancing the level of scaffolding (guidance offered by the system) or by the level of freedom to explore the material. The results imply that educators and designers need to pay attention to how the supporting and scaffolding mechanisms of AES are used in the curriculum.

Furthermore, AES should be designed to make their maintenance and updating (by educators) easy, in order to ensure that such systems are practical in an educational environment. To achieve this, a level of technical simplicity needs to be adopted for the creation and maintenance of such systems.

As the need for using web based educational materials increases in secondary schools, the demand for the use of adaptive hypermedia systems that cater for a variety of learning approaches will increase. While there is still an enormous amount of research to be undertaken in the field of the design and usability of adaptive hypermedia systems, this research has endeavoured to resolve some of the pertinent issues facing the educators. The results of this study are encouraging enough to warrant more exploration in this area. As more instruction becomes delivered via adaptive hypermedia environments, learners will need strategies and cognitive tools to help them in the acquisition of knowledge.

Future studies should address the problems of sampling error, limited sample size, and pre-test/post-test questioning type. The elimination of these deficiencies will create a more reliable measure of the research questions posed.

The findings of the first experiment imply that the design of learning/teaching environments according to a student's preferred learning styles affect the level of student knowledge gain. In summary, a student's experience with adaptive online hypermedia systems seems to play an important role in improving knowledge gain and learning experience.

It is worth noting that overall, this research supports the argument that environments can be formulated in such a way to enhance the performance of learners with different learning preferences using AES. For the researches in the field of AHS, the results of this study reiterate the importance of learning style and strategy differences among individuals, especially in the design of the learning environment to support these differences.

Appendix A Case study LSAS

This questionnaire shows a number of screenshots of the user interface of LSAS system.

Select your Learning Style

Following your visit to the Learning Style Questionnaire, you should now know whether you are a global or a sequential learner.

Please select the correct choice from the two options below:

[Sequential] [Global]

Figure A.1 Learning style selection at the start

Ozone Session

Welcome back Namira Bajraktarevic. Click on the link below to start the ozone session.

Start the ozone session

Pre Questionnaire for Ozone

Please fill in the answers for the missing words in the boxes.

1 The role of ozone in the Earth's atmosphere is shielding us from UV- radiation. (A, B, or C)

2 Ozone degradation is caused by human made chemicals called .

3 Ozone consists of atoms of oxygen.

4 A product that relies on a pressurized gas to propel substances out of a container, that used to be used in consumer products such as deodorants is called an ? (specify the substance - singular) .

5 The instrument that measures the intensity of solar UV radiation at four wavelengths is called the Dobson .

6 The protocol signed in Montreal by 49 countries agreeing to reduce the production of CFCs is called the protocol.

7 The effect of warming earth' caused by entrapment of greenhouse gasses is called global .

8 A term used for rain and other precipitation that is polluted mainly by sulphuric acid and nitric acid is called rain.

9 The warming that results when the earth's atmosphere traps the sun's heat and it is created by carbon dioxide, methane, and other atmospheric gases, which allow sunlight to reach the earth but prevent heat from leaving the atmosphere is called the effect.

10 An amendment to implement the Montreal Protocol in the United States that provided a schedule for phasing out the production and use of specific ozone-depleting chemicals and that mandates phasing out HCFCs beginning in 2015, with a complete ban on production after 2030, and phasing out methyl bromide by 2001 is called the ' Air' act.

[Send answers]

Figure A.2. Pre test for matched session

Post Questionnaire for Ozone

Please answer all the question below by filling in the missing word. The correct answers you gave earlier in the pre-questionnaire are shown again here.

1 The role of ozone in the Earth's atmosphere is shielding us from UV-b radiation. (A, B, or C)

2 Ozone degradation is caused by human made chemicals called ______ .

3 Ozone consists of ____ atoms of oxygen.

4 A product that relies on a pressurized gas to propel substances out of a container, that used to be used in consumer products such as deodorants is called an ? (specify the substance - singular) ______ .

5 The instrument that measures the intensity of solar UV radiation at four wavelengths is called the Dobson ______ .

6 The protocol signed in Montreal by 49 countries agreeing to reduce the production of CFCs is called the ______ protocol.

7 The effect of warming earth' caused by entrapment of greenhouse gasses is called global ______ .

8 A term used for rain and other precipitation that is polluted mainly by sulphuric acid and nitric acid is called ______ rain.

9 The warming that results when the earth's atmosphere traps the sun's heat and it is created by carbon dioxide, methane, and other atmospheric gases, which allow sunlight to reach the earth but prevent heat from leaving the atmosphere is called the ______ effect.

10 An amendment to implement the Montreal Protocol in the United States that provided a schedule for phasing out the production and use of specific ozone-depleting chemicals and that mandates phasing out HCFCs beginning in 2015, with a complete ban on production after 2030, and phasing out methyl bromide by 2001 is called the 'clean Air' act.

Completed Session 2

Well done Namira Bajraktarevic, you have completed the second session and have been logged out of the system. Your details have been stored.

You scored 3/10 on the ozone quiz.

You can click here to close this browser window

Thank you Namira Bajraktarevic. Your answers have been stored and checked, you may now continue with the material.

Countries Pages (sequential)

Figure A.3. Post test for matched session and transfer to mismatched session

Pre Questionnaire for Countries

Please complete the sentences by typing the answers into the boxes.

1 A poor country or LEDC has low GNP and a rich country has (specify low or high)GNP

2 Wealthier regions of a country are called core and poorer regions are called

3 The region in Brazil that contributes most to GNP is situated in south - ..

4 Three main economic indicators of development are GNP, trade and .

5 Two main social indicators of development are health, care and

6 The low death rate, the percentage of people living in urban areas and a trade surplus are three main characteristics of (Insert LEDC or MEDC).

7 Italian industry is centered in the north, in Milan-Turin-Genoa, which is called .. ...(2 words)

8 Capital of Brazil is

9 The main lanugage spoken in Brazil is

10 GNP stands for

Send answers

Countries Session

Welcome back Namira Bajraktarevic. Click on the link below to start the countries session.

Start the countries session

Figure A.4. Pre test for mismatched session

Post Questionnaire for Countries

Please answer all the question below. The correct answers you gave earlier in the pre-questionnaire are shown again here.

1 A poor country or LEDC has low GNP and a rich country has (specify low or high)GNP

fsdf

2 Wealthier regions of a country are called core and poorer regions are called

3 The region in Brazil that contributes most to GNP is situated in south - ..

4 Three main economic indicators of development are GNP, trade and .

5 Two main social indicators of development are health, care and

6 The low death rate, the percentage of people living in urban areas and a trade surplus are three main characteristics of (Insert LEDC or MEDC).

7 Italian industry is centered in the north, in Milan-Turin-Genoa, which is called .. ...(2 words)

8 Capital of Brazil is

9 The main lanugage spoken in Brazil is

10 GNP stands for

Send answers

You scored **3/10** on the countries quiz.

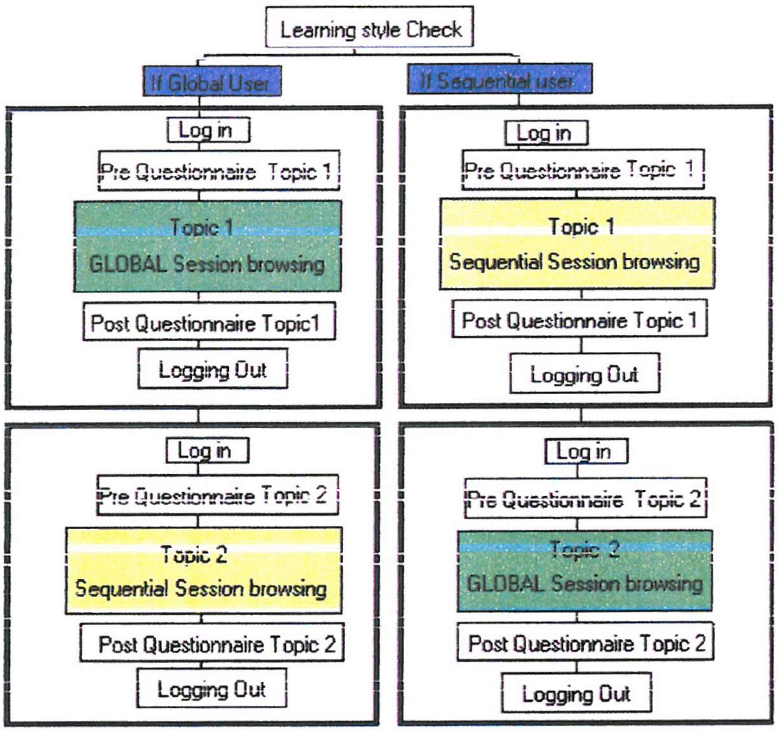
Thank you for completing the experiment: you can close your browser now!

Figure A.5. Post test for mismatched session

Appendix B Usability Study LSAS

This appendix shows the steps of the usability study for the first experiment, the online background questionnaire, Index of learning styles, attitude questionnaire and the expert opinion reviews of the LSAS system.

Sequence of the steps involved in the exercise:



Having been to an external web site you will know your learning style and then :

1. You will log on and choose appropriate exercise to go through (global or sequential)

2. Go through "Preliminary Knowledge Level" questionnaire on particular session for Topic 1

3. Go through the Learning Style session (global or sequential)

4. After completing the above, go to Post Knowledge Level Questionnaire for that session

5. Repeat the steps 3, 4 and 5 for Topic 2 (Countries)

6. Log out

Proceed to the Logon page

Figure B.1. The description of steps involved in the usability study

Appendix B Usability Study LSAS

I A M

Intelligence, Agents, Multimedia Group, Southampton University

Background Questionnaire

Thank you very much for agreeing to participate in the experiment. The purpose of this questionnaire is to study the usefulness of a customized user interface. All of your personal data that we collect will be entirely confidential, viewed only by the experimenters. But first, we would like to collect your previous computer experience background information, which will help us better interpret the effectiveness of our experiment.

Please complete the following:

[1] Which of the following computer environments have you used?

- ☐ Unix terminals
- ☐ Windows environment
- ☐ Point_and_click environment
- ☐ Hypertext environment

[2] What type of browser do you use?

- ☐ Microsoft Internet Explorer
- ☐ Netscape
- ☐ Neoplanet
- ☐ Other

[3] Actions performed on the WWW

- ☐ Authoring
- ☐ Browsing
- ☐ Searching
- ☐ Downloading and uploading files
- ☐ Sending emails

[4] How skilled are you at using a computer?

[Never used one ▾] (Please select an option from the list)

[5] Please indicate your level of skill for each of the following

	Good	Average	Low	None
Word Processing	○	○	○	○
Spreadsheets	○	○	○	○
Databases	○	○	○	○

Email				
Web Browser				
Programming				
Authoring HTML				
Image Editing				
Newsgroups				
Multimedia				
Web based learning				
Discussion groups				
Searching library catalogue				
Searching the WWW				
Searching on CD-ROM				

[6] Do you have a computer at home?

- Yes
- No

[7] Time spent working on computer in a day

Installation

- Don't
- Under 2 hours
- Between 2 and 4 hours
- More than 4 hours

Playing games

- Don't play games
- Under 2 hours
- Between 2 and 4 hours
- More than 4 hours

Browsing

- Don't browse
- Under 2 hours
- Between 2 and 4 hours
- More than 4 hours

Sending Email

- Don't use Email
- Under 2 hours
- Between 2 and 4 hours
- More than 4 hours

Appendix B Usability Study LSAS

[8] Where do you mainly use the Internet?

- at home
- at school/college
- at a library
- at a friend's house
- other

[9] How long have you been using the Internet?

- less than a month
- 1-2 months
- 3-5 months
- 6-12 months
- 1-2 years
- over 2 years

[10] How confident are you using a computer?

- very confident
- confident
- not confident

[11] How often would you say you use a computer

- every day
- every 2-3 days
- once a week
- once a month
- less than once a month
- never

Submit answers

Figure B.2. The demographic questionnaire posed at the start of using LSAS

Appendix B Usability Study LSAS

Background questionnaire results

The following section describes the feedback obtained for each one of these questions.

User's experience with using computers

All 5 students indicated that they use the Internet every day, 3 of them said that they are very confident using computers. 2 of them said that they have been using the Web for over 2 years, 1 student between 1-2 years and 1 student between 6-12 months. The background questionnaire show that all students have good skills base using the majority of common computer based activities, as word processing, web based media, e-mail, image editing spreadsheets and databases.

Time spent on PC

The results of students' feedback show that when using a PC, the students tend to spend the most of their time sending e-mail, followed by browsing the WWW (2-4 hours a day) and playing games.

Student's use of different environments on PC

Almost all of the students used the Microsoft Windows environment coupled with the use of MS I.E. 5, which was the browser that the software was tested with. It was presumed that the familiarity with these environments should help student navigation.

Student's search experience on PC

With regards to the experience performing a variety of computer based searching. It was found that the majority of the students thought that their experience of searching the WWW and CD ROMs was good, followed by average experience for searching library catalogues. This question was posed to because a search feature was incorporated in system software. See Appendix B for a complete listing of questions asked in the Background questionnaire.

Appendix B Usability Study LSAS

http://www2.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/ilsweb.html

NC STATE UNIVERSITY

Index of Learning Styles Questionnaire

Barbara A. Soloman
First-Year College
North Carolina State University
Raleigh, North Carolina 27695

Richard M. Felder
Department of Chemical Engineering
North Carolina State University
Raleigh, NC 27695-7905

Directions

Please provide us with your full name. Your name will be printed on the information that is returned to you.

Full Name

For each of the 44 questions below select either "a" or "b" to indicate your answer. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently. When you are finished selecting answers to each question please select the submit button at the end of the form.

1. 1. I understand something better after I
   - **(a)** try it out.
   - **(b)** think it through.
2. 2. I would rather be considered
   - **(a)** realistic.
   - **(b)** innovative.
3. 3. When I think about what I did yesterday, I am most likely to get
   - **(a)** a picture.
   - **(b)** words.
4. 4. I tend to
   - **(a)** understand details of a subject but may be fuzzy about its overall structure.
   - **(b)** understand the overall structure but may be fuzzy about details.
5. 5. When I am learning something new, it helps me to
   - **(a)** talk about it.
   - **(b)** think about it.
6. 6. If I were a teacher, I would rather teach a course
   - **(a)** that deals with facts and real life situations.
   - **(b)** that deals with ideas and theories.
7. 7. I prefer to get new information in

(a) pictures, diagrams, graphs, or maps.
(b) written directions or verbal information.

8. 8. Once I understand
(a) all the parts, I understand the whole thing.
(b) the whole thing, I see how the parts fit.

9. 9. In a study group working on difficult material, I am more likely to
(a) jump in and contribute ideas.
(b) sit back and listen.

10. 10. I find it easier
(a) to learn facts.
(b) to learn concepts.

11. 11. In a book with lots of pictures and charts, I am likely to
(a) look over the pictures and charts carefully.
(b) focus on the written text.

12. 12. When I solve math problems
(a) I usually work my way to the solutions one step at a time.
(b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. 13. In classes I have taken
(a) I have usually gotten to know many of the students.
(b) I have rarely gotten to know many of the students.

14. 14. In reading nonfiction, I prefer
(a) something that teaches me new facts or tells me how to do something.
(b) something that gives me new ideas to think about.

15. 15. I like teachers
(a) who put a lot of diagrams on the board.
(b) who spend a lot of time explaining.

16. 16. When I'm analyzing a story or a novel
(a) I think of the incidents and try to put them together to figure out the themes.
(b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. 17. When I start a homework problem, I am more likely to
(a) start working on the solution immediately.
(b) try to fully understand the problem first.

18. 18. I prefer the idea of
(a) certainty.
(b) theory.

19. 19. I remember best
(a) what I see.
(b) what I hear.

20. 20. It is more important to me that an instructor
(a) lay out the material in clear sequential steps.
(b) give me an overall picture and relate the material to other subjects.

21. 21. I prefer to study

(a) in a study group.

(b) alone.

22. 22. I am more likely to be considered
   - (a) careful about the details of my work.
   - (b) creative about how to do my work.
23. 23. When I get directions to a new place, I prefer
   - (a) a map.
   - (b) written instructions.
24. 24. I learn
   - (a) at a fairly regular pace. If I study hard, I'll "get it."
   - (b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."
25. 25. I would rather first
   - (a) try things out.
   - (b) think about how I'm going to do it.
26. 26. When I am reading for enjoyment, I like writers to
   - (a) clearly say what they mean.
   - (b) say things in creative, interesting ways.
27. 27. When I see a diagram or sketch in class, I am most likely to remember
   - (a) the picture.
   - (b) what the instructor said about it.
28. 28. When considering a body of information, I am more likely to
   - (a) focus on details and miss the big picture.
   - (b) try to understand the big picture before getting into the details.
29. 29. I more easily remember
   - (a) something I have done.
   - (b) something I have thought a lot about.
30. 30. When I have to perform a task, I prefer to
   - (a) master one way of doing it.
   - (b) come up with new ways of doing it.
31. 31. When someone is showing me data, I prefer
   - (a) charts or graphs.
   - (b) text summarizing the results.
32. 32. When writing a paper, I am more likely to
   - (a) work on (think about or write) the beginning of the paper and progress forward.
   - (b) work on (think about or write) different parts of the paper and then order them.
33. 33. When I have to work on a group project, I first want to
   - (a) have "group brainstorming" where everyone contributes ideas.
   - (b) brainstorm individually and then come together as a group to compare ideas.
34. 34. I consider it higher praise to call someone
   - (a) sensible.
   - (b) imaginative.
35. 35. When I meet people at a party, I am more likely to remember

(a) what they looked like.

(b) what they said about themselves.

36. 36. When I am learning a new subject, I prefer to
    - (a) stay focused on that subject, learning as much about it as I can.
    - (b) try to make connections between that subject and related subjects.

37. 37. I am more likely to be considered
    - (a) outgoing.
    - (b) reserved.

38. 38. I prefer courses that emphasize
    - (a) concrete material (facts, data).
    - (b) abstract material (concepts, theories).

39. 39. For entertainment, I would rather
    - (a) watch television.
    - (b) read a book.

40. 40. Some teachers start their lectures with an outline of what they will cover. Such outlines are
    - (a) somewhat helpful to me.
    - (b) very helpful to me.

41. 41. The idea of doing homework in groups, with one grade for the entire group,
    - (a) appeals to me.
    - (b) does not appeal to me.

42. 42. When I am doing long calculations,
    - (a) I tend to repeat all my steps and check my work carefully.
    - (b) I find checking my work tiresome and have to force myself to do it.

43. 43. I tend to picture places I have been
    - (a) easily and fairly accurately.
    - (b) with difficulty and without much detail.

44. 44. When solving problems in a group, I would be more likely to
    - (a) think of the steps in the solution process.
    - (b) think of possible consequences or applications of the solution in a wide range of areas.

When you have completed filling out the above form please click on the Submit button below. Your results will be returned to you. If you are not satisified with your answers above please click on Reset to clear the form.

Submit Query | Reset

Last Updated: June 29, 1999 .bh

Dr. Richard Felder, felder@eos.ncsu.edu

Figure B.3. Index of Learning Styles–Soloman and Felder (1988)

Appendix B Usability Study LSAS

Attitude Questionnaire

Attitude Test

Now that you have finished the session, this questionnaire will allow you tell us how useful you found the system.

Please complete the following:

Presentation and guidance

1. The layout of information was clear.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

2. Colouring of links was appropriate (blue for unvisited, purple for visited links).

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

3. Visual cues were very helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

4. Search button was very helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

5. Summary was very helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

6. Overview of the topic was very helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

7. Additional information was very helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

8. 'Next' button and the associated description was very helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

9. The number of links was too high.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

10. The number of links too low.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

11. There was too much text displayed at any one time was in Global session.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree

- ❑ Totally disagree

12. There was not enough text at any one time in Sequential session.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

Exploration and navigational freedom

13. The system allow moving around pages as I wanted to .

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

14. I did not feel disorientated at any point.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

15. I found access to the table of contents (TOC) helpful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

16. I found myself just 'scanning' the text and links in order to answer questic

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

17. There enough reference information/ links available were useful.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

18. I found the structure of the course material ordered appropriately.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

Overall impressions

19. The course material was well presented and understandable.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

20. The learning objectives were clear.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

21. The methods of assessment were clear.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

22. The system was reliable.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

23. The system was easy to use.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

Improvements

24. Provide better information about the course.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

25. Clarify the course objectives further.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

26. Reduce the content covered in course.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

27. Increase content covered in course.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

28. Make the course activities more stimulating.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

29. Improve the organisation of the course.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

30. Slow down the pace of the course.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

31. Reduce the time taken for the course.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

32. Reorganise the structure of the content in a more concise way.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

33. Provide multimedia elements.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

34. Provide more computer training before using the application.

- ❑ Strongly agree
- ❑ Agree
- ❑ Neither
- ❑ Disagree
- ❑ Totally disagree

Submit answers

Thank you for filling-in this questionnaire and participating in this study.

Figure B.4. Attitude Questionnaire

Appendix B Usability Study LSAS

Expert opinions reviews

As part of the usability study four independent evaluators were involved in the study. The team comprised of people with different skills: teachers, user interface design experts, learning style enthusiast and software testers. Each evaluator performed the test individually and each performed a different type of evaluation. Some experts were asked to perform a walkthrough, some to review educational content and some to perform a predictive evaluation. In all, the experts looked critically at the system, rationalized the good and bad aspects of the design choice and formulated potential improvements. Data gathered by the expert was of a quantitative nature and was returned via e: mail. The issue they came across were divided into:

a) Serious problems (such as: system stops responding, not allowing a log in)
b) Intermediate problems (such as broken links that would stop users from proceeding browsing)
c) Trivial problems (such as inconsistencies in the layout)

1. The cognitive walkthrough approach showed the following issues:

1] ***IB**: User interface designer*

This expert performed a walkthrough evaluation method, i.e. went through the user's scenarios. This is the list of his comments and improvement suggestions.

- **Design improvement**

Access to back /next buttons
Broken links
Removing white space
Ensuring consistency by adding a search button on each page
Font size too small, indentation incorrect

- **Testing the pages on a low spec computer**

Reduce column widths so that the page will be visible on a monitor with limited resolution

- **Reduce the content amount on each page**

There is far too much information to take in at one sitting.

- **Improve 'Keywords' Page**

Few of the keyword links jump to exactly the right place.
Also there is a lot of wasted space again – the margins at the sides could be smaller. Also the Keywords themselves do not appear to be in alphabetic order.

- **Be consistent with the font and background colour**

This is in a completely different style and font to all other previous footnote pages seen thus far.

- **Downloading Flags and Maps Page to be speeded up**

I would consider putting the Flags on a separate page to the maps. Remember, these might be downloaded from a web site; it will be slow to load.

- **Eliminate spelling errors**

- **Provide some fast track method for them to get started**

The Intro page should contain a lot less information. Remember it is students who will start reading this. At the very least you should provide some fast track method for them to get started – without having to read all that information

- Comments on the **Getting Started** page

The tables layout needs improvement – the table width is greater than the screen width and again – the full screen is not used efficiently. The table formatting on the Intro page could be improved – the titles are larger than the columns. You could explain the navigation buttons in a column on the right or something.

- **Clarify the connection to the learning styles questionnaire**

It would be worth opening the Questionnaire link in a new window, so that their starting page remains open.

- Allow for students to stop and start using the system at any point and consequently come back to where they left off
- Improvement in logging out after the question of learning styles
- Use a consistent approach when suggesting the options available in the Ozone questionnaire
- Place restrictions on the number of characters the user can enter.
- Might be worth mentioning to the students need not read all the information in order to complete the tests
- Change the link colour so that they appear visited
- All pages should have the same background colour as the other pages to ensure consistency; the user shouldn't have to learn keep re-learning the interface as well as the topic.
- The page arrangement could be improved to reduce or remove the need for scrolling
- Ensure that users know which page of the lesson you are on where there are more than one.

21 GK: network administrator with extensive system testing experience

Comments:

- Too much content
- The level too high for the students
- Sessions taking too long to perform

Suggestions:

- Ensure that lessons are not longer than school periods (45 mins)
- Ensure that the users can stop and re-start browsing the system at any point in time
- Ensure that the errors are more user-friendly

3] *RC: Learning styles enthusiast and college teacher*

This expert examined the system from the learning style-incorporation-and-representation point of view.

Comments:

- Material not particularly interesting
- May have motivation problems
- Choice of LSQ: relies on good self awareness
- Navigational elements good with overviews, signposting
- Descriptions of further information: too linear, heavily language based
- System didactic and controlling
- Learning styles are represented more in the layout than in its form and content

Improvements suggested:

- Introduce colour coding of ideas and concepts
- Add more images
- Let the system become more interactive
- Add 'what if' scenarios for global users

4] *PF: Secondary education teacher and content expert*

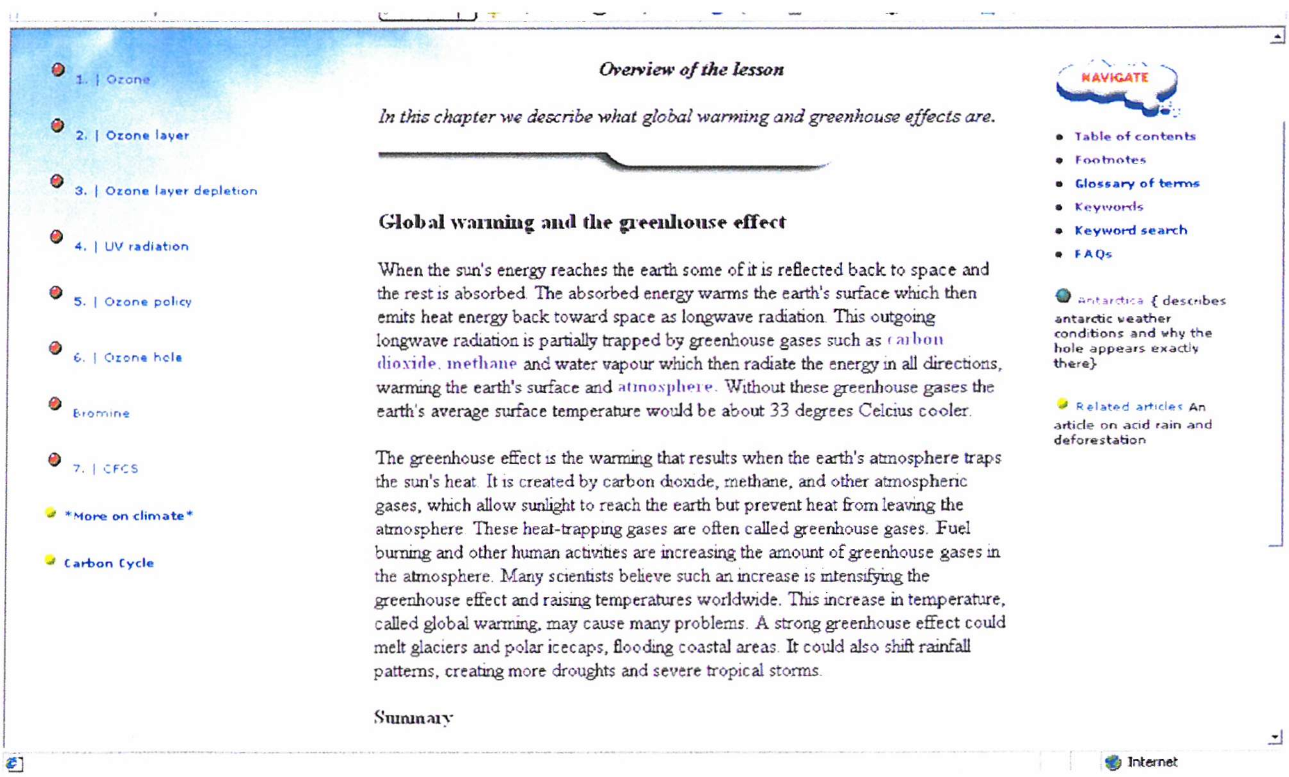
This expert examined the system from educational point of view.

Recommendations for improvement:

- Introduction pages: Instructions to be clearer and shorter
- Use of LSQs to be explained better for sequential users
- Knowledge level is above GCSE level and needs to be replaced
- Language level is to be more appropriate to GCSE user level
- Summative evaluation needs to be performed including observation

Appendix C Global and Sequential learning style templates

(1) Global page layout



(2) Sequential page layout

Italy : Economy

Italy began to industrialize late in comparison to other European nations, and until World War II was largely an agricultural country. However, after 1950 industry was developed rapidly so that by the 1990s industry contributed about 35% of the annual gross domestic product and agriculture less than 4%. The principal farm products are fruits, sugar beets, corn, tomatoes, potatoes, soybeans, grain, olives and olive oil, and livestock (especially cattle, pigs, sheep, and goats). In addition, much wine is produced from grapes grown throughout the country. There is a small fishing industry.

Industry is centered in the north, particularly in the "golden triangle" of Milan-Turin-Genoa. Italy's economy has been gradually diversifying, shifting from food and textiles to engineering, steel, and chemical products. The chief manufactures of the country include iron, steel, and other metal products; refined petroleum; chemicals; electrical and nonelectrical machinery; motor vehicles; textiles and clothing; printed materials; and plastics. Although many of Italy's important industries are state-owned, the trend in recent years has been toward privatisation. The service sector has growing importance in Italy; by the early 1990s it employed well over half of the labour force.

< Back Next >

A.2. Learning style representation

i. Global learning styles representation in the interface layout

Global students have a so-called 'top-down' or 'inverted pyramid' approach to acquiring and processing information. This style refers to having an overall picture of the oncoming text before fitting the details in, and then finally synthesizing the information into an overall picture. To assist global students (U_G) in 'scanning text' the following things were included in the design of the learning materials used for this study:

- Emphasise important text by using bulleted lists and sub headers
- Present lots of text within one page
- Provide guidance/suggestions
- Provide link descriptions on 'Next'&'Back' buttons
- Provide a summary and overview of the chapter
- Provided examples and links to related concepts
- To reduce the amount of detail on the pages, use bulleted lists and headers

ii. Sequential learning styles representation in the interface layout

The sequential template, containing a very basic page-by-page layout, was designed so that the structure and links within this template were synonymous with the structure of traditional sequential material. The sequential material is broken into smaller parts. This is a representation of the "bottom-up" approach to acquiring and processing information, constructed by collecting together relevant course parts in sequence. This style refers to reading details and then synthesising information into an overall picture. To assist sequential students (Us), the following elements were incorporated into the student interface:

- The lessons were linked in a logical sequential order
- Information was presented step by step
- There were no overviews or summaries of the lessons to prevent distraction
- The text was split up into smaller chunks between pages or split into smaller parts within one page
- No diagrams on the pages, but links to them were provided
- No examples or analogies were provided
- The overall picture was presented at regular intervals between chapters to assist in synthesising information
- Access to the table of contents and the graphical interpretation of textual information was provided but at a much more discrete level. This was done in order to prevent confusion.

Appendix D Empirical results LSAS

Student No (1).	Time spent browsing (min.sec) (2)	(3)	d=T2-T1 (min.sec) (4)	Rank of d (5)	Sign (6)
	T1 (Session1)	T2 (Session2)			
1	24	1.04	(-)22.96	-18.0	(-)
2	14	9.52	(-)4.48	-4.0	(-)
3	4	19.37	15.37	10.0	(+)
4	13	19.03	6.03	6.0	(+)
5	15	15.44	0.44	1.5	(+)
6	10	8.53	(-)1.47	-3.0	(-)
7	6	26.22	20.22	14.0	(+)
8	29	13.58	(-)15.42	-11.0	(-)
9	36	26.35	(-)10.35	-8.0	(-)
10	1.18	32.23	31.05	20.0	(+)
11	47	25.26	(-)21.74	-16.0	(-)
12	15	15.51	0.51	2.0	(+)
13	48	27.55	(-)20.45	-15.0	(-)
14	2.13	29.35	27.22	19.0	(+)
15	22	3.39	(-)18.61	-12.0	(-)
16	16	16.44	0.44	1.5	(+)
17	18	27.43	9.43	7.0	(+)
18	24	13.54	(-)10.46	-9.0	(-)
19	8	27.5	19.5	13.0	(+)
20	29	34.52	5.52	5.0	(+)
21	2.09	24.42	22.33	17.0	(+)

Table D.1. Wilcoxon matched pair test results for the difference between means of browsing times for matched and mismatched sessions

Appendix E Case Study ILASH

This appendix shows a number of screenshots for the case study for the second experiment, where learning strategies were adapted. It includes post-test after adaptive and non adaptive sessions.

Welcome

If you are a registered user, please enter your username and password below.

Username: [ ]

Password: [ ]

[login]

Figure E.1. The online login screen

You are about to be transferred to the waves end test. Here you will need to answer 6 questions connected to what you have read about in this section.

Note: Again, once you start this test you will not be able to return to the page about waves. To continue to the test click the button, "Contine to the test", otherwise follow the link back to the index.

[Continue to the test] Return to the waves index

Figure E.2. The screenshot of the message informing user about the post test, after browsing waves session

Intelligence, Agents, Multimedia Group, University of Southampton

Knowledge Test-Behaviour of Waves

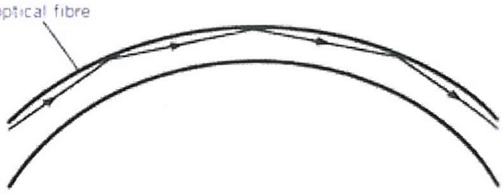
Marks

1. Match the waves from each type of radiation to its use

UV rays	Please select from this list
Microwaves	Please select from this list
X rays	Please select from this list
Infra red waves	Please select from this list
Gamma rays	Please select from this list

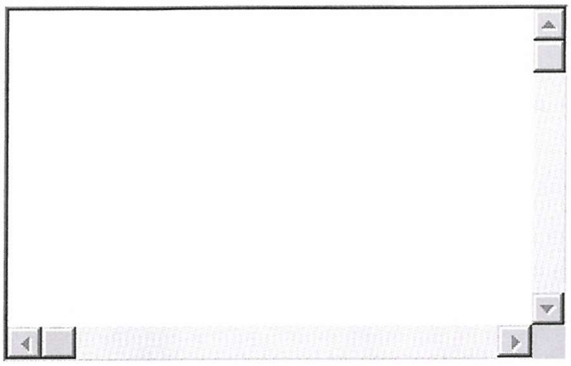
Total marks for this section (max 5)

2. The diagram below shows a ray of light passing through an optical fibre.



Explain why the ray of light stays in the optical fibre.

Explain also two other conditions the light pipe must satisfy, in order to allow total internal reflection.



Total marks for this section (max 3)

3. Copy and complete the following sentence about waves:

Waves travelling across the surface of water are [ ] waves.

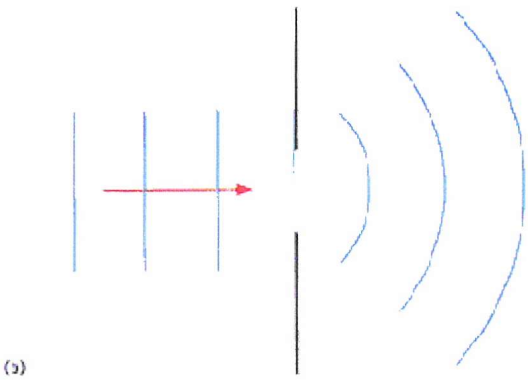
The disturbance in the water is [ ] the direction in which the wave is travelling.

Sound waves in air are [ ] waves.

The disturbance of the air is [ ] the direction in which the waves are travelling.

Total marks for this section (max 4)

4. Summarise the process of diffraction of waves and the relationship between the gap size and the light wavelength. Explain how diffraction of waves can affect certain types of radio waves.



a) When the French physicist Leon Foucalt showed that the speed of light in water is slower in water than its speed in air, he confirmed that the light behaves as ______. When Sir Isaac Newton expected the edges of shadows of objects to have 'fuzzy' edges, rather than the sharp edges that we actually see, he thought of light as ______.

b) What is the name given to sound waves of frequency higher than 20 000 Hz?

'Long wave' radio waves have a wavelength of about 1km. Why can you still receive long wave broadcast even when there is a hill between you and the transmitter?

The waves get ______ by objects such as hills.

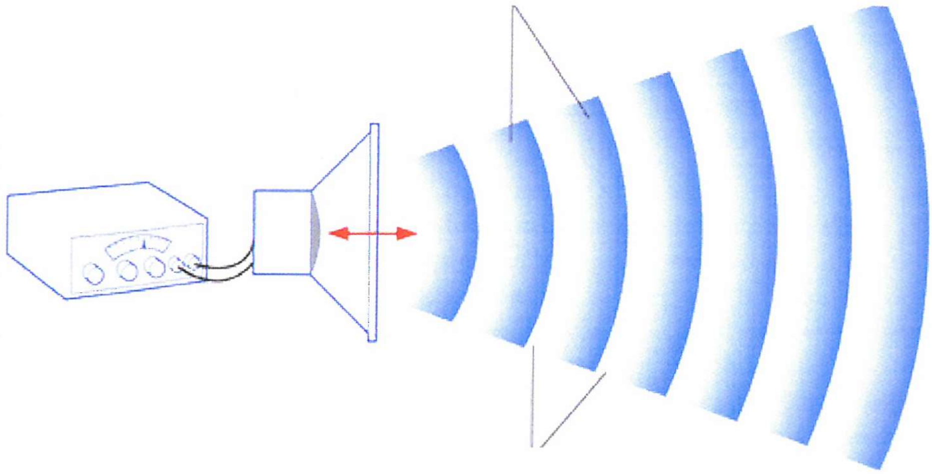
Total marks for this section (max 7)

5. Sound waves.

a) Explain **four** similarities and **ONE** difference between sound waves compared to the light waves.

b) Look at the diagram below and explain what can be used to measure and detect sound waves.

c) What is simple way of creating such a device and how do you measure waves?



d) Explain the relationship between the strength and the pitch of the sound and the amplitude and frequency of the waves:

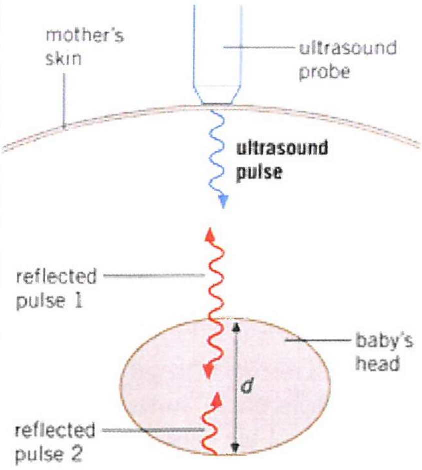
What happens to the loudness of the sound when the amplitude increases?

What happens to the pitch of the sound as the vibration becomes faster?

e) Explain how the ultrasound waves are produced.

Total marks for this section (max 6)

6. Identify how ultrasound waves can be used to measure the diameter of an unborn baby's head. The picture shown below should help you.



Total marks for this section (max 2)

Submit

Total marks for the test (max 27)

Figure E.3. The post test after adaptive session in ILASH

End of Session

Thank you.

Your answers to the **waves end questionnaire** have been stored.

You can close the browser window by clicking here

Or you can return to the login page here (next: The Solar System)

Figure E.4. A message informing user that the adaptive session is completed

Intelligence, Agents, Multimedia Group, University of Southampton

Knowledge Test - Solar system

Questions — **Marks**

1. The table shows data about some of the planets in our solar system

Planet	Time to orbit Sun once (years)	Time to rotate once on axis (days)	Gravitational field at surface (N/kg)	Approximate average distance from Sun (million km)
Mercury	0.24	59	4	58
Venus	0.6	243	9	110
Earth	1.0	1	10	150
Mars	1.9	1	4	230
Jupiter	12	0.4	26	780
Saturn	30	0.4	11	1430
Pluto	248	6	4	5900

Which planets take longest to go around the Sun?

Which planets have the longest day?

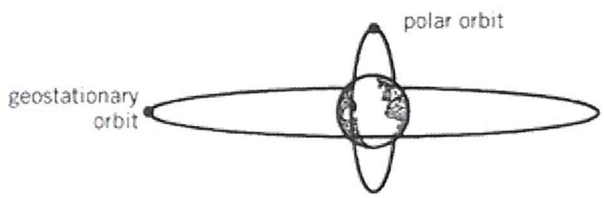
Which planets have the shortest day?

Which planets are the furthest from Sun?

Which planet has the highest gravitational field at the surface?

Total marks for this section (max 5)

2. The diagram below shows circular orbits for two satellites around the Earth.



one?

State **two purposes** why satellites can be put in orbit.

Total marks for this section (max 3)

3. Copy and complete the following sentence about solar system:

How long does it take a geostationary satellite to complete an orbit? [ ]

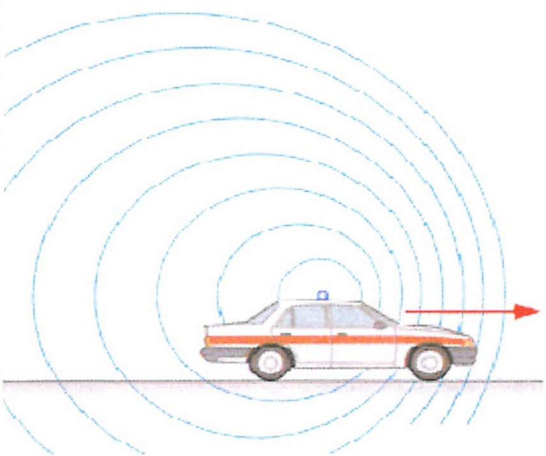
Telecommunication satellites are usually placed in [ ] orbits.

Our observation of the Universe suggests that it may have started off in a gigantic explosion, which scientists call [ ] [ ].

The name of the satellite that provided scientists with important evidence about the origin of the Universe was called [ ] satellite.

Total marks for this section (max 4)

4. Explain in your own words what the Doppler effect is. Include the relationship between the wavelength and the sound waves. If it helps, use the analogy of the car approaching and passing by you.



Identify what happens to the wavelength and pitch of a sound waves when you

a) Approach an object

The wavelength ______ and the pitch ______.

b) When you move away from an object

The wavelength ______ and the pitch ______.

Total marks for this section (max 7)

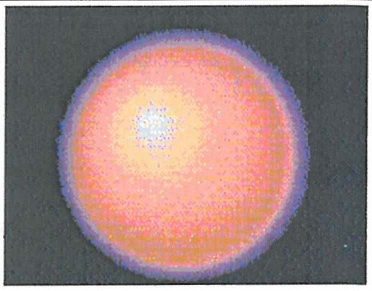
5. At the end of the stable stage of its life a star will change.

Explain the changes that could take place for a star to become :

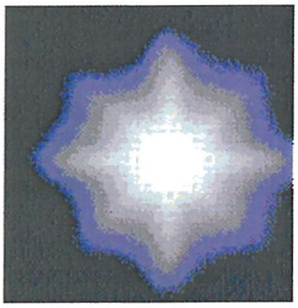
1) A white dwarf

2) to become a black hole

3) **to become a red giant**

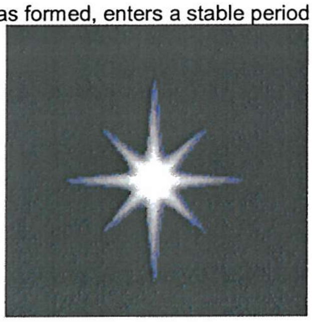


4) a supernova



5) a neutron star

6) Once the star that has formed, enters a stable period in its life, it is known as a



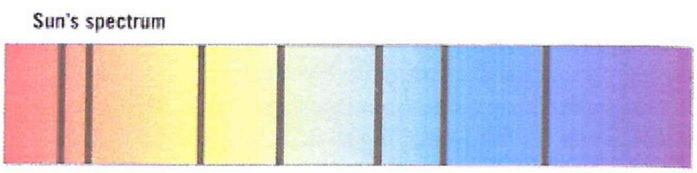
star.

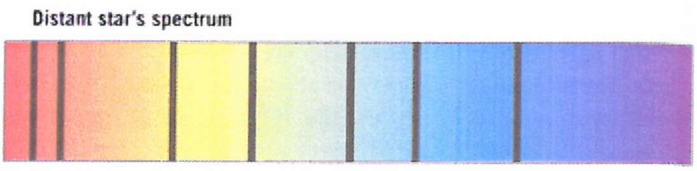
Total marks for this section (max 6)

6. Look at the diagram below and explain the main ideas behind the red shift effect, i.e.

a) what happened to a distant star

b) why it happened





Total marks for this section (max 2)

Submit

Total number of marks for the test (max 27)

Figure E.5. The post test after NON adaptive session in ILASH

Appendix F Usability Study ILASH

This appendix shows usability study instructions, attitude questionnaire and subjective feedback for the second experiment, where the system ILASH was tested.

Usability study instructions

To take part in this usability study , you will need to perform the following steps:

1. Log into www.login.ecs.soton.ac.uk/~nb99r/physics/index.htm. You will be asked to enter your

username and the password already given to you.

2. Browse the first half of the test- the topic is 'The solar system'. (30 mins)

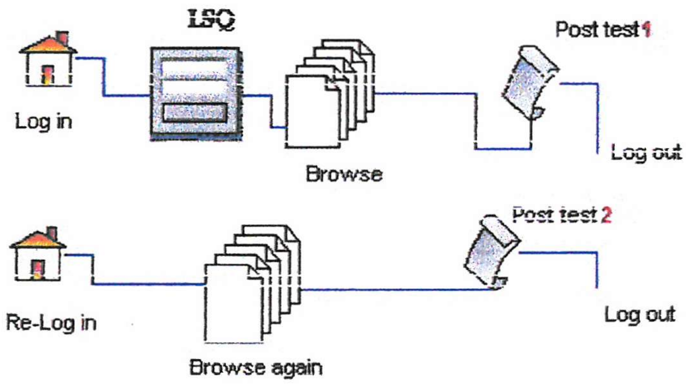
3. Answer a post-test1. (6 questions) (25 mins)

4. Re-login, and access another topic- 'Behaviour od the waves'. In this session you will be prompted to

answer questions throughout. (30 mins)

5. Answer the post-test2. (6 questions) (25 mins)

6. Fill in an attitude questionnaire. (10 mins)



If you encounter any issues that will prevent you from proceeding in the experiment , please send a message to

Namira and you will get a very prompt response. Many thanks for taking part in this study.

Figure F.1. The introduction page to the usability study instructions

Appendix F Usability Study ILASH

Your opinion on the system

Please tick appropriate answer (example: Agree (√))

Presentation

The layout of text in the adaptive version of the system was clear
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

The structure of text in the adaptive version of the system was clear
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

The change in the layout between questions asked before the paragraph and the key point summarised after each paragraph wee useful
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Colouring of links was appropriate (blue for unvisited, purple for visited links)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

There were too many links to follow in the adaptive version of the system
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Exploration and navigational freedom

The adaptive version of the course well was presented
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

The learning objectives were clear
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

The adaptive version of the system was easy to use
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Adaptive features of the system

Adaptive toolbar positioned on the right hand side of the pages showing me the links of what I have read, what I am currently reading and what else is available to read, was useful in browsing
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Adaptive progress bar in table of contents that showed my progress through the system was useful
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Annotation of links (different colours of links) helped me navigate through the system
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Hiding of links in the table of contents allowed me to proceed through the course at appropriate pace
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Key points summarised after each paragraph helped me learn better
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Questions asked after each lesson helped me learn better
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Switching between two-system layouts when I provided incorrect answer was helpful
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

I prefer the table of contents with the percentage of my progress through the system than the ordinary table of contents (like in 'The Solar system' version)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

Appendix F Usability Study ILASH

SUMI ASSESSMENT

I found the system overwhelming to use (AFFECT)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

I managed to complete the course in timely fashion (EFFICIENCY)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

It was easy to become familiar with the system quickly (LEARNABILITY)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

The errors that occurred were helpful (HELPFULNESS)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

The system responded to my inputs in a consistent way (CONTROL)
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

<u>Overall impressions of the adaptive system</u>

I liked the structure of the lessons in the adaptive system
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

I liked having some of the links hidden in the adaptive system
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

I preferred the adaptive (Behaviour of the waves) to the non-adaptive (The solar system) versi of the system overall
Agree ( ) Strongly Agree ( ) Strongly Disagree ( ) Disagree ( ) Neither ( )

<u>Additional comments</u>

Thank you for your participation

Figure F.2. Attitude and SUMI questionnaire presented after using ILASH

Appendix F Usability Study ILASH

Usability study –Expert Review and Students Comments

Student1: M1

Comments:

- The box is quite small in the final questionnaire on waves.
- Too much content
- Sessions taking too long to perform
- Questions on waves section (wavelength & frequency) have wrong answer
- Missing pictures from ideas and evidence pages (top bar)
- Sidebar not seen on some wider pages (motions of the planets- solar session)
- Titles from the pages missing in solar section
- Dead links in solar system session

- *Suggestions:*

- Increase the size of the 'suggestions' box in the attitude questionnaire
- A 'search this site for...' button would be useful if for example you only wanted to know about lets say 'diffraction' definition.
- A more detailed summary at the beginning telling you what would change if you got questions wrong.
- As well as being told what would happen with your logged questions.
- Stop Java errors redirecting to directory.
- A final question page with tick boxes like on the summary would also be good.
- Allowing +1 for a correct answer -1 for a wrong answer and a 'pass' button. This would encourage people to try and get the correct answer.
- Testing their knowledge so far. A 100 secs timer would also make sure nobody cheated looking the answers up.
- A database of answers could be made and 15 could be show each time. A hi-score table could also be incorporated into the design.
- Alert the user to what has changed when the site adapts.
- Secure the password function

Student2: A1

Improvements suggested:

- The end of chapter questions should relate to the things just done - not something covered after. (in the second section especially)
- The navigation bar down the side was not clear or helpful.
- Where the navigation bar is it would be useful to have a summary of what has been done so far
- Many of the end-of-chapter questions only required you to move the pop-up window and look at a diagram to answer.
- The diagrams are easier to understand than the text.
- The tree-view structure on the main page was distracting and not very useful. A list would have been better.
- The solar system end-of-chapter links were broken.
- XML was not the best choice as not everyone uses IE and even people who do might not be using the latest version (IE 5+ include a XML parser, but very few others.). HTML or XHTML would have been a better choice.
- Black on white is not the most engrossing colour scheme, and a simple but more interesting one would have held the readers attention to the page better - along with better layout.
- More sections would have made it better.
- There were JavaScript errors on the Solar System part in the tree view as it had no items in it.
- This box needs to be bigger.

Student3:Ri

Comments:

- If the questions are opened in a new window u can look through page and answer at same time
- Font a bit small, maybe change as well to Arial
- (Tool tips) on pictures s a little odd: is S intentional?
- The correct answers are more commonly the top ones
- Picture VERY fuzzy and found it hard to read the text next to the picture
- Spelling errors
- I just got a question wrong, and it said the learning mode has been changed. This is bit confusing, clarify a bit more
- I like the whole progressing theme

Recommendations for improvement:

- Increase the font size
- Modify the answers to questions so that the top answer is not always the correct one
- Write the description of the pages in the title, i.e. make titles of the pages more descriptive and relevant to the content
- Add tool tips for images so that they are more descriptive
- Testing the pages on a low spec computer -Reduce column widths so that the page will be visible on monitor with smaller resolution (800x600)
- Rephrase a question on total internal reflection
- Make sure that the questions are not opened in the new window
- 'Star's life page does not work
- Search button should state it is search for definitions or glossary of terms

Student4: M2

Comments and suggestions

- This site makes the course very easy to understand and an easy way to learn the course.
- If you had a small test at the end that was just multiply choice, I think it would add an extra incentive to do well. Basically add in a scoreboard so they can see the top 20 people and where they are.
- A database of 150 questions, which it randomly picks 10, would be fine and not too repetitive. To stop the problem of people just guessing, a point should be taken away for each incorrect answer and there should be a pass button if you don't know.

Student5: Al2

Comments and suggestions:

- The way it went through the questions did not always relate to material just covered.
- To keep peoples interest more the layout and colours on the site could do with being improved. I found myself not even bothering to look at the sidebar, as it usually had nothing more in it than just pressing next would do, and on the odd occasions it did I did not notice.
- XML is not a good choice, as a large number of people with other browsers would be locked out, the same with the JavaScript menus, which are really unnecessary. Normal HTML would have done just as well

Appendix G Adaptive features of ILASH

(1) Adaptive Toolbar

Figure G.1. A changing look of the toolbar during interaction with the system

(2) Adaptive table of contents

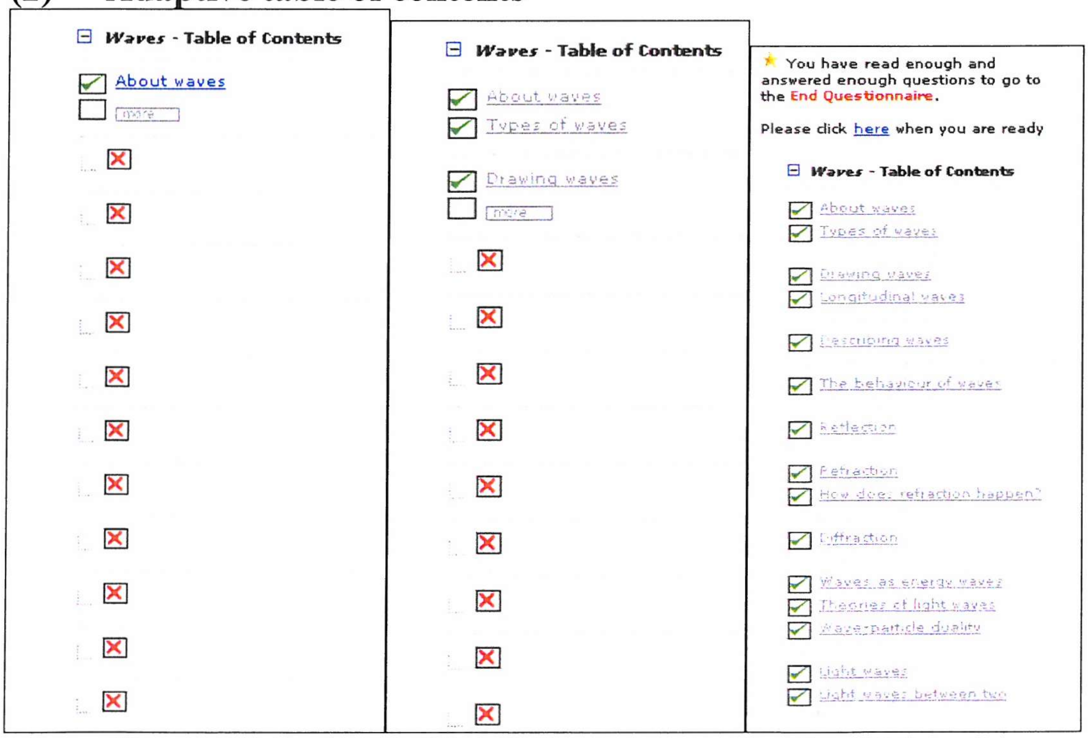


Figure G.2. A changing look of the table of contents during interaction with the system

Appendix H Empirical evaluation ILASH

This appendix presents tables of the lengths of browsing times for adaptive and non-adaptive sessions. It also presents the tables of score gains.

Browsing times for adaptive and non adaptive sessions

	Time difference	Number of students
	0- 5 mins	3
	5-30 mins	3
	30- 50 mins	2
	More than 60 mins	1
Average	**33.50 mins**	**Total: 9**

Table H.1. Browsing times increase in the non-adaptive session

Out of 52 students 9 (~17.6%) spent more time on non-adaptive session, while 42 students (~82.4%) spent more time on the adaptive session. Out of 51 students, only 9 students spent more time on non-adaptive session, with 33.5 mins on average.

	Time difference	Number of students
	0- 5 mins	3
	5-20 mins	17
	20- 40 mins	13
	40 -70 mins	9
Average	**29.44 mins**	**Total: 42**

Table H.2. Browsing times increase in the adaptive session

Table H.2. shows that the rest of the students (42) spent more time on adaptive session, on average 29.44 mins. The results from the above two tables contradicts the expectation that the students would spent more time on non-adaptive session

Relationship between score gains and percentage of the students

	Score gains	Number of students (%)
	0-5 points	19 (37.25)
	5-10 points	17 (33.33)
	10-15 points	2 (3.92)
Total		**38 (74.51)**
Average	**5.98 points**	

Table H.3. Score gains and percentage of students

Out of 51 students who completed the experiment, 75% of them obtained a score increase. Average score gain between two sessions for this number of the students was 5.98 points. More than one third of the students (37.25%) achieved score gains of 5 points or less. One third of the students (33.33%) also achieved around average score gain (5-10 points), while a small percentage of the students (3.92%) achieved high score gains (more than 10 points difference) between the two sessions.

Appendix J User Management

This appendix shows the screenshots of user management tools used for LSAS and ILASH.

(1) User Management Tool in LSAS

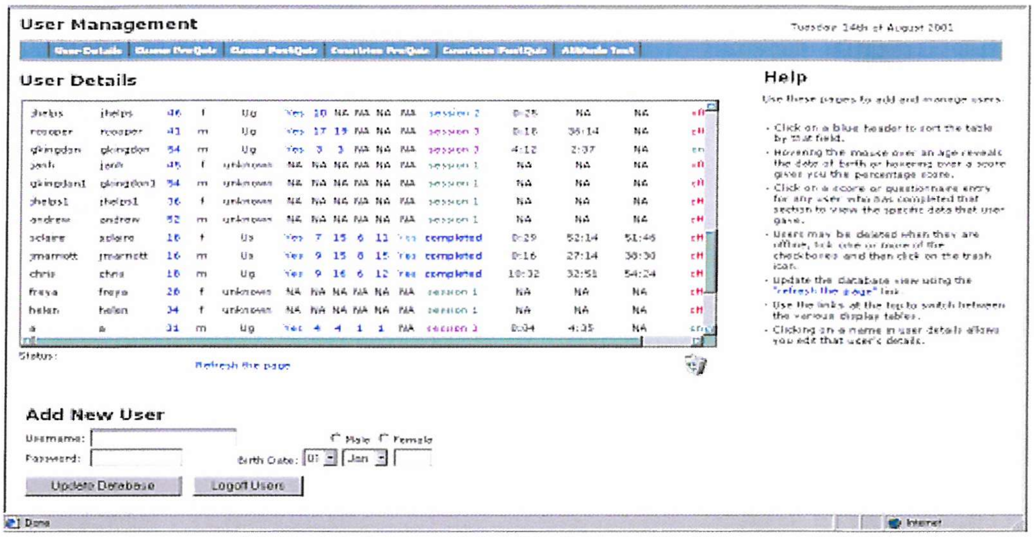
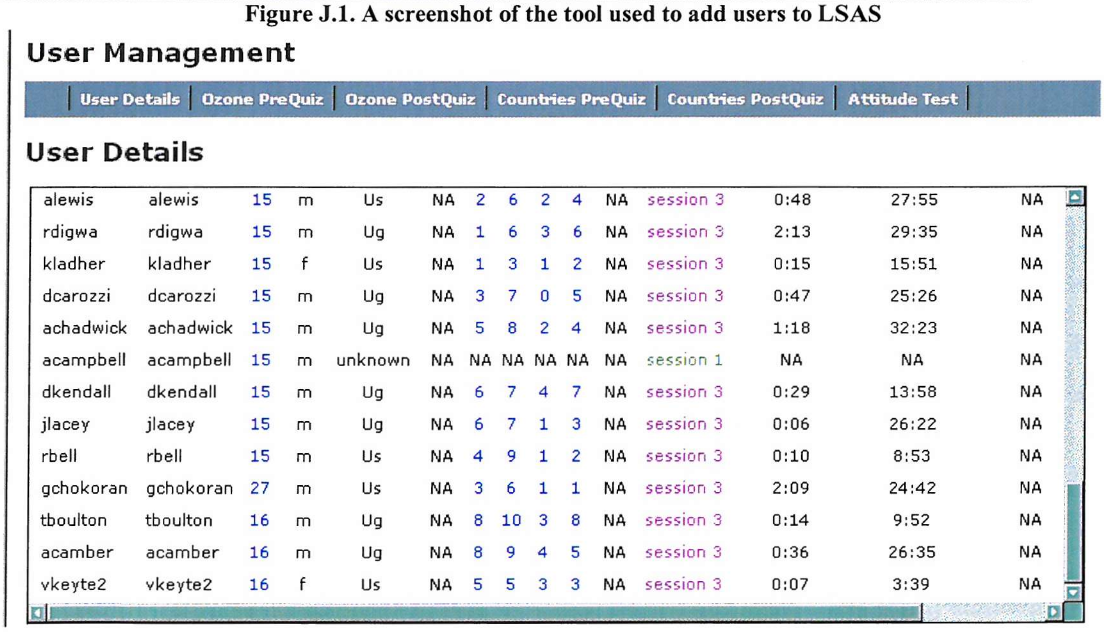


Figure J.1. A screenshot of the tool used to add users to LSAS


User Management

User Details	Ozone PreQuiz	Ozone PostQuiz	Countries PreQuiz	Countries PostQuiz	Attitude Test

User Details

alewis	alewis	15	m	Us	NA	2	6	2	4	NA	session 3	0:48	27:55	NA
rdigwa	rdigwa	15	m	Ug	NA	1	6	3	6	NA	session 3	2:13	29:35	NA
kladher	kladher	15	f	Us	NA	1	3	1	2	NA	session 3	0:15	15:51	NA
dcarozzi	dcarozzi	15	m	Ug	NA	3	7	0	5	NA	session 3	0:47	25:26	NA
achadwick	achadwick	15	m	Ug	NA	5	8	2	4	NA	session 3	1:18	32:23	NA
acampbell	acampbell	15	m	unknown	NA	NA	NA	NA	NA	NA	session 1	NA	NA	NA
dkendall	dkendall	15	m	Ug	NA	6	7	4	7	NA	session 3	0:29	13:58	NA
jlacey	jlacey	15	m	Ug	NA	6	7	1	3	NA	session 3	0:06	26:22	NA
rbell	rbell	15	m	Us	NA	4	9	1	2	NA	session 3	0:10	8:53	NA
gchokoran	gchokoran	27	m	Us	NA	3	6	1	1	NA	session 3	2:09	24:42	NA
tboulton	tboulton	16	m	Ug	NA	8	10	3	8	NA	session 3	0:14	9:52	NA
acamber	acamber	16	m	Ug	NA	8	9	4	5	NA	session 3	0:36	26:35	NA
vkeyte2	vkeyte2	16	f	Us	NA	5	5	3	3	NA	session 3	0:07	3:39	NA

Figure J.2. A screenshot of user details stored by the LSAS system

(2) User Management Tool in ILASH

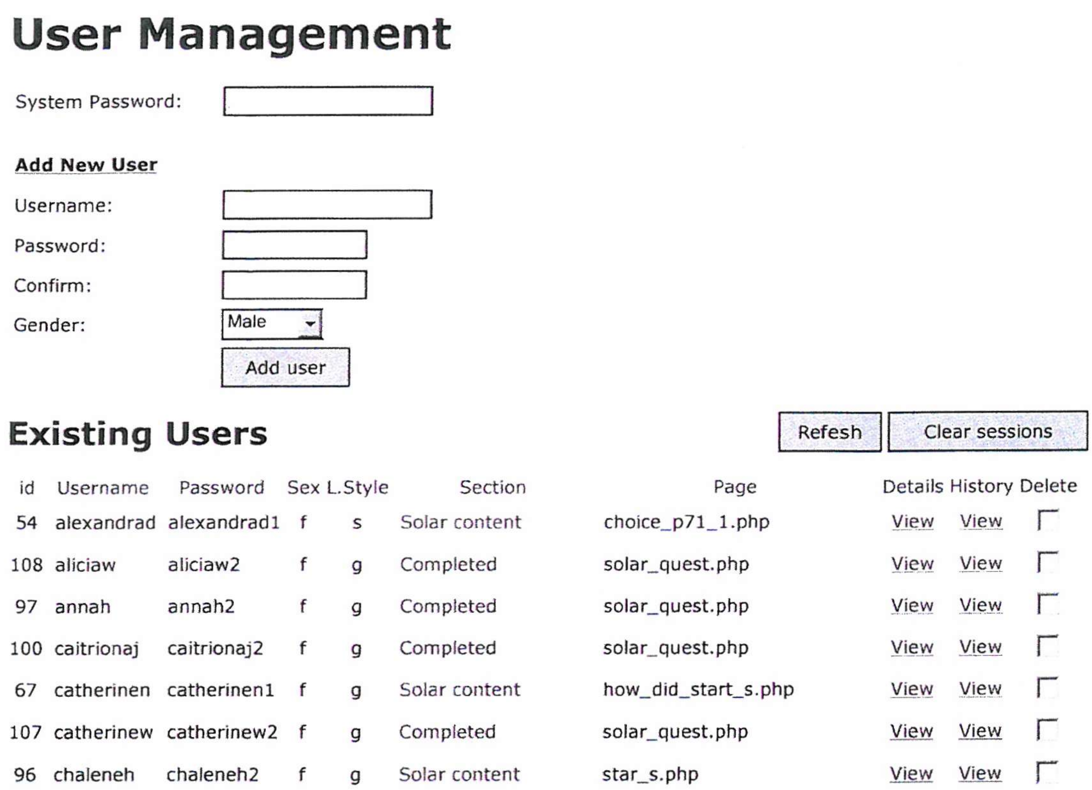


Figure J.3. A screenshot of the tool used to add users to ILASH

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