An Investigation into the use of Multimedia for Electronic Learning

Marek R. Oledzki

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ABSTRACT

Electronic learning (e-learning) has been very much in vogue over the last few years and has stimulated significant interest from groups of various backgrounds. This heightened state of interest in the field of e-learning has caused many companies, organisations and institutions to try to rapidly develop and implement newly accessible learning technologies in an attempt to capitalise on the perceived market potential. To a large degree, this has led to fundamental learning theories being sidelined and the focus being set on the more glamorous technologies. Against this background, the work presented here is concerned with an investigation into the use of learning technologies within education and commercial training, specifically focussing on how multimedia is used within these learning technologies and the effects of multimedia in general within electronic learning. This is facilitated by a series of experimentations with a custom designed multimedia learning package, based on the subject of visual perception.

The experimental learning material is designed, authored, and produced using a number of commercially available multimedia authoring packages, such as 3D Studio Max, Macromedia Director & Flash, Adobe Photoshop & Illustrator. The production is modelled on the commonly used instructional system design methodology model: Analysis, Design, Development, Integration and Evaluation (ADDIE). The multimedia learning material comprises of 3-dimensional models that are animated, and explanatory audio narration. The multimedia learning material is compared against a more traditional text and illustration based learning material using pre and post test evaluations. Attitude questionnaires and feedback forms are employed to collect participants' opinions for additional context. The results are presented and statistically analysed.

The results of the research, if somewhat limited in context, show that no significant difference is recorded between participants studying the multimedia learning material and those studying the traditional learning material. This important result is discussed in relation to fundamental learning theories, highlighting the apparent negative benefit of using animation and audio based learning material. However, when taken into context, the results are used as a basis for a more positive and potentially useful discussion of the factors that influence multimedia learning; namely - motivation of the learning material as an positive effect, using audio within multimedia learning & presentations, material & teacher regulation, learning environments and the attitudes of participants toward multimedia material.

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List of abbreviations

ADDIE	–	Analysis, Design, Development, implementation & evaluation.
CAL	–	Computer Aided Learning
CBT	–	Computer Based Training
CMI	–	Computer Mediated Instruction
DC	–	Dublin Core
DTD	–	Document Type Definition
DVD	–	Digital Versatile Disk
ICT	–	Information Communication Technology
IMS	–	Instructional Management Systems
ISD	–	Instructional System Design
ITS	–	Intelligent Tutoring System
ITS	–	Intelligent Tutoring System
LMS	–	Learning Management System
LOM	–	Learning Object Metadata
MLE	–	Managed Learning Environment
MPEG	–	Motion Picture Engineering Group
PDA	–	Personal Digital Assistant
RDF	–	Resource Definition Framework
RSS	–	Really Simple Syndication
SCROM	–	Sharable Courseware Object Reference Model
SGML	–	Standard Generalised Mark-up Language
SMIL	–	Synchronised Multimedia Integration Language
TLM	–	Traditional Learning Material
VLE	–	Virtual Learning Environment
VLP	–	Virtual Learning Portal
VOD	–	Video On Demand
W3C	–	World Wide Web Consortium
WBT	–	Web Based Training
XHTML	–	Extensible Hyper Text Mark-up Language
XML	–	Extensible Mark-up Language

1 Introduction

1.1 Introduction

Many aspects of our daily lives have experienced profound change since the explosion of Information Communication Technology (ICT) in the early 1990's. It is now customary across the vast majority of the developed world for personal or professional needs to communicate, collaborate, organise and function utilising the benefits that ICT has brought. The internet, the World Wide Web and vast array of services it offers has grown beyond comprehension, with figures suggesting around 532,897 Terabytes of information being stored virtually (Lyman 2003), compared to the amount of printed text typically created in the world each year at 160 Terabytes (Lesk, 1997). Hard disks store most new information, some ninety-two percent of this new information being stored on this magnetic media. With all these changes that are affecting the way information is created and disseminated it is not surprising that learning has followed suit.

The development of new information communication technologies is opening new opportunities for distributed education to reach students and learners at a distance, but also to serve the need for flexibility. Compression technologies, combined with exponentially improving computer processing capabilities at reduced costs, internet, and wireless communications are making access to interactive, multimedia instruction readily available to home and the work environment (Truman, 1995; Qual E-learning Project Consortium, 2004).

Distance education and learning are not a new phenomenon; this type of schooling has existed for many years with institutions such as the Open University in the UK (http://www.open.ac.uk) exemplifying one of the most successful implementation of distance learning. However, the possibilities and potential of ICT has generated substantial interest from a number of groups in the way that the distance learning process may be organised enhanced and accelerated. The result is what we call "e-learning", a term that is very much in vogue, and which has generated a variety of definitions.

Being firmly positioned in the early stages of the technological revolution as depicted in figure 1.1, many distance educators are rushing in a hope to capitalise on the large revenue to be had from a global market and to become the distant educators of tomorrow. Many are doing so without having addressed a number of key issues that will determine the success or failure of their efforts. E-learning is being hailed and synonymously associated with better and more efficient learning outcomes. But is this merely hype?

To address this question, numerous studies have been undertaken in an attempt to analyse and evaluate the efficiency of e-learning environments. Kulik and Kulik (1991) reported increased knowledge acquisition using computer based tools as opposed to traditional learning methods. Other studies, such as Software Publishers Association (1995), Kazmerski & Blasko (1999) and Steyn, du Toit et al. (1999) support these results. Interestingly other studies have not been so supportive, and show different outcomes in the use of educational technology. Fricke (1991) reported only slight or no differences while Merchant, Kreie et al. (2001) investigated computer based training and found it to be less effective than normal instructional modes. On analysis of these studies it can be concluded that a blind approach to using educational technology for learning does not in itself produce desired results. However, e-learning models based on sound instructional strategies that adhere to accepted learning theories and psychologies will advance the cause of learning mediated by technology (Kumar 2004). "E-learning needs to be seen as judicious harnessing of technology to realise positive gains".

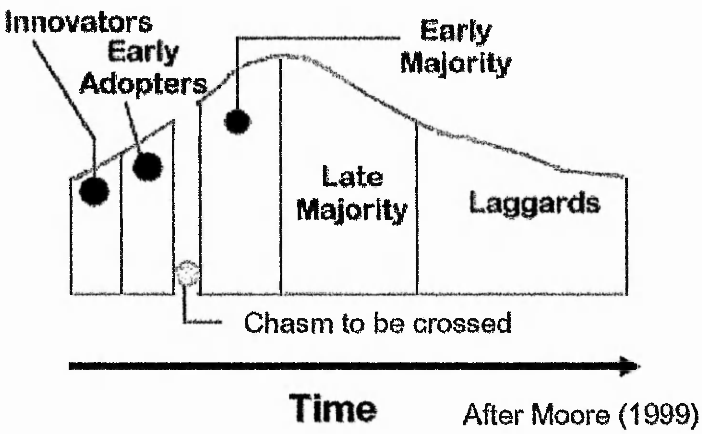


Figure 1.1 Moore's curve for the rate of technology adoption. E-learning is understood to be in the 'early adopters' stages of development and the 'chasm to be crossed' refers to the difficult task of transgression into a more generally adopted technology.

1.2 Aims and objectives

This research project commenced by asking what is e-learning and what role multimedia has to play in the field of e-learning? The following research questions were formulated and explored:

a) Is there true value in the use of electronic learning material or is e-learning just hype?
b) How effective is it?
c) Is electronic learning more effective than traditional methods?
d) Does using multimedia in electronic learning make for more effective learning?
e) How effective is multimedia learning and what are the main factors that influence e-learning?

The aim of this research was to investigate the most appropriate use of multimedia based distance learning techniques for training of personnel in the audio-visual information displays industry.

The following objectives were formulated:

- Firstly, to understand learning theory and the vast array of learning technologies.

- To analyse the pedagogical and instructional value of these electronic learning technologies; in particular comparing multimedia learning against more traditional methods by investigating the differences in effectiveness and appropriateness.

- To undertake a review of current literature on the above topics.

- To produce, author and evaluate electronic based learning module for use as a learning / teaching aid for the subject of visual perception.

- To review preliminary results, experimental procedures and evaluate the prototype electronic learning module with a view of enhancing for further experimentation.

- Statistical analyse the research results, investigate further issues raised from the results, discuss and finally present the work in a research thesis.

The practical experimentation within this research centres on investigating the effectiveness of different combinations of multimedia content on learning outcomes and retention by recording participants in a series of evaluations. Two main sets of experiments are performed, one using electronic multimedia, and one using traditional text and diagrammatical representations. Responses from participants with regards their attitudes towards the experimental material are also recorded by the use of questionnaires and feedback forms.

2 Background Review

2.1 Definitions

The term "distance education" has become widely used in most informed discussion and related literature of educational technology. Historically, distance education meant correspondence education. However, over recent years the term "distance learning" has been adopted when referring to any education at a distance. Hess (2000) simply states, "Distance education is the most widely used term to connote a system in which educator and learner are separated by physical distance".

Lorraine Sherry (1995) defines distance education as situations where the instructor and students are in separate locations or times where control of learning is held by the learner rather than the instructor and communications are mediated between teacher and student by print or technology.

Berge (1998) explained the difference between distance education and distance learning. "Distance education was seen as the formal process of distance learning, with wide range of information," for example, university degree courses. While distance learning was defined as "the acquisition of knowledge and skills through mediated information and instruction, encompassing all technologies and other forms of learning at a distance." (Wentling, 2000)

Hess also adds that the educational community have opted to drop the term 'education' with reference to distance education as it does not emphasis the students' involvement in the learning process, the definition of distance education has much influence on defining distance learning and the terms are therefore used interchangeably. The emphasis in both these definitions is on the distance element of the process.

A fuller definition is given by Jones (1996) "Distance learning has the following characteristics; The separation of the teacher and learner, planning and preparation of learning material by an educational organisation, use of media, often print-based, to carry course content and to unite teacher and student, some form of two way communication and students learning as individuals".

As software's, technologies and paradigms for teaching and learning have evolved, several terms have been fashioned to characterise the innovations and concepts developed. These additional terms have lead to confusion when dealing with the electronic form of distance learning and distance education.

These terms include…

- Computer based training
- Blended learning
- Online learning
- Web-based learning/training
- Hybrid learning
- Computer aided learning
- Distributed learning
- Net-based training
- Electronic learning
- Collaborative learning
- Mobile learning
- Adaptive learning
- Networked learning

Zahm (2000) described computer based training (CBT) as usually a multimedia based training program that is typically accessed via the internet as a download, or on a CD-ROM. Karon (2000) defines CBT by focusing on the convenience aspect of the training identifying importance of self paced progression of a learning course, in comparison to the rather strict traditional instructed course. Like CBT, Gotschall (2000) outlines online learning as a general term that refers to all training done with a computer over a network, be it a local area network or a world wide network, the internet. Additionally Gotschall added that online learning is also known as net-based training.

Hall (2000) defined Web-based training as instruction that is delivered over the internet or intranet of a company accessible through the use of a Web-browser. With the two above definitions being so similar, Web-based training can be assumed to be online learning.

E-learning, according to National Centre for Supercomputing Applications (NCSA) review of definitions, is the acquisition and use of knowledge distributed and facilitated primarily by electronic means. This form of learning currently depends on networks and computers but will likely evolve into systems consisting of a variety of channels (e.g. wireless networking, satellite), and technologies e.g., cellular phones, PDA's as they are developed and adopted. E-learning can take the form of courses as well as modules and even smaller learning objects. E-learning may incorporate synchronous or asynchronous access and may be distributed geographically with varied limits of time. More recently (and particularly in corporate US) some practitioners speak of distributed learning and collaborative learning. These terms are intended to emphasise community based learning distributed globally rather than a closed environment of the individual learner. The community is comprised of learners, educators, distant learning systems and curriculum materials.

Other definitions of e-learning include:

- The Open and Distance Learning Quality Council (UK) describes e-learning as an "…effective learning process created by combining digitally delivered content with (learning) support and services"(http://www.odlqc.org.uk/odlqc/n19-e.htm).

- For the Learning Skills_Council's Distributed and Electronic Learning Group (DELG) (UK) distributed and electronic learning (DEL) "…can be represented as a spectrum ranging from Internet-supported distance learning in which the learner has limited physical contact with a tutor or other learners, to teacher-led, classroom-based activity which is interspersed with occasional computer-delivered or facilitated assignments"(http://www.lsc.gov.uk/westyorks/Documents/Eleraning.htm).

- For the European commission, e-learning is characterised as "The use of new multimedia technologies and Internet to improve the quality of learning by facilitating access to resources and service as well as remote exchanges and collaboration"(http://www.elearningeuropa.info/).

2.2 Research topics within e-learning

Hype surrounding e-learning has produced statements such as "E-learning is transforming education", "e-learning provides access to a wealth of resources and new forms of communication and virtual communities", within research journals, conferences and the media. But in reality e-learning is still not fully understood and has not yet fulfilled its promise and potential with respect to innovative learning products, systems, models and frameworks (Conole, 2004). For example the rapid downfall in 2004 of the £50m flagship e-learning organisation UKeU, a collaboration between Higher Education Funding Council England (HEFCE), Sun Microsystems and UK universities, where there were only 140 students using the platform in June 2004. Former chairman of the UKeU holding company Sir Brian Fender explained that demanding business plans were too difficult to fulfil and that "there was probably too much hype. There was some feeling that digital technologies would move faster than they have".

The UKeU is not alone. Computing (Computing 2005) spent 18 months investigating the state of elearning and in addition to UKeU, the newspaper revealed issues for concern at National Health Service University (NHSU) and University for industry (Ufi) finding that Ufi generated just £995,018 from businesses and individuals in 2003, having so far spent almost £1bn of public money.

Technologies undoubtedly have a great deal to offer to education, however within this multi discipline area much research has been carried out and a further continuation of research is required to enable differentiation between the hype and true gains and bring about a literal understanding and acceptance of how the technological aspect of e-learning can be utilised effectively.

Over the last ten years there has been a distinct movement away from the focus on technology, with more emphasis on information and content, since these are central to learning technologies. The Joint Information Systems Committee (JISC 2004) forcing this issue through the redefining of e-learning to 'enhanced learning' rather then 'electronic learning'. This reflects an augmented learning process rather then emphasising the electronic aspect of e-learning. Hence the move has sided towards communication and collaboration aspects of e-learning. Nevertheless, the full potential that ICT offers has yet to be harnessed and fundamental questions of how ICT can be used to enhance learning need to be addressed (Ravenscroft, 2003).

E-learning research has seen a substantial growth over the last decade with numbers of researchers joining the field from an array of disciplines, for example education, computer science, design and multimedia, mathematics and psychology. This growth in research and development has seen a number of academic, corporate based organisations and consortiums form (JISC; Educause; IMS Global consortium; The e-learning research centre, eLRC; Nesta futurelab; E-learning centre; Elearnspace; for full list see appendix A), a number of dedicated conferences (ALT-C; MERLOT Teaching and Technology; EdMedia; Networked learning;) and an even greater number of journal publications have materialised.

With e-learning drawing on a number of different schools of research and underlying theories, it is as of yet not entirely defined area (Conole, Cook and Ingranham, 2003) and suffers from not being recognised alongside other established fields. Despite this, e-learning does draw on a range of disciplines, its research and the long history of interest in enhancing educational processes with the use of technology (Mason, 2002). The underlying theories and influences may be grouped into three main areas of research: **pedagogical, technical, organisational and contextual.**

Pedagogical and technical issues are the main focus of this review and make up the majority of the rest of this chapter. Organisational issues within e-learning deal with the users, understanding of how they work and the mechanisms and procedures involved in developing electronic learning systems and also include structures and processes of how skills and activates arising from electronic learning align with institutional issues. Also included in organisational issues are factors of context and culture. These issues consider the influence of particular local context and culture on organisational issues, the barriers that are presented by these issues and the management of these. Contextual issues deal with legal and ethical issues associated with the security of information sharing, data protection, confidentiality and how plagiarism is to be detected and dealt with. Also included in contextual issues are questions of how accessibility and cultural and linguistic differences are being addressed. Organisational and contextual issues are referred to in the thesis where appropriate, however, are not covered in detail during this review chapter.

2.3 Pedagogical and psychological principles of E-learning

To examine the effects of multimedia on e-learning, it is necessary to acquire some understanding of how people learn. The model, types of memory, and processes included in these theories also appear in more specific theories described later in this section.

Sensory Store

Learning is "the act of deliberate study of a specific body of material, so that the material can be retrieved at will and used with skill" (Norman, 1982, p. 3). According to general human learning theory (for example, Norman, 1982), new knowledge is first received by a sensory store such as a briefly retained visual image (iconic memory) or auditory memory (echoic memory).

Short-term Memory

Information in the sensory store can be transferred to a low capacity, short-term working memory using top-down processing or bottom-up processing. Top-down processing, or conceptually guided processing, is controllable by the person, uses conscious resources, and proceeds down from the higher conceptual levels. Bottom-up processing or data-driven processing, is more automatic, not as much under the person's control, and probably does not use conscious resources. Bottom-up processing proceeds from the sensory data, pulling out relevant features to create the information that the sensory data represent. Once in the working memory, information can be kept there by rehearsing it.

Working memory may not be a single storage area, but a set of storage systems that are coordinated by a "central executive". Baddeley (1983, 1988b,) proposed separate systems for verbal and pictorial information. For example, auditory information such as speech is retained in verbal working memory called the articulatory loop system. This type of working memory helps people comprehend speech. Visual, spatial information such as images are retained in visual memory called the visuo-spatial sketch pad. This type of working memory helps people retain and manipulate visual information when performing tasks such as using recalled images to count the number of pictures on the walls of their rooms. The existence of separate, coordinated working memory systems is supported by a study (Logie, Zucco, & Baddeley, in Baddeley, 1988a) in which people performed two tasks simultaneously that involved working memory.

Long-term memory

To transfer information from the low capacity, short-term working memory to the high capacity, long-term memory, the person searches the long-term memory for connections to the information in short-term memory. These connections organise the new information from a large number of independent units into a smaller number of organised groups of units.

The process of moving information from the short-term memory to the long-term memory is called encoding. Encoding connects new knowledge to prior knowledge. This process can be improved when the person elaborates (elaborative processing) on the information (Anderson, 1980, 1983; Anderson & Reder, 1979). The person connects the information in short-term memory to information in long-term memory. Encoding the same information differently appears to improve recall (Madigan, 1969).

Another technique that is believed to improve the transfer of information from short-term memory to long-term memory is to manipulate the levels (or depth) of processing of the information (Craik & Lockhart, 1972). According to this approach, the way an item is processed affects memory for that item. Processing the physical characteristics of an item is thought to be "shallow," so memory for that item should be poor. Processing the meaning of an item is thought to be "deep," so memory for that item should be good.

It is easier to learn new information if it can be put it into an existing knowledge framework.
New knowledge depends on old knowledge. According to Norman (1982), "The more one knows, the easier it is to learn more." Prior knowledge helps people understand and remember information because new information can be: (1) made more meaningful, (2) incorporated into existing knowledge, and (3) retrieved with existing retrieval schemes.

2.3.1 Fundamental learning theories

Learning theories and philosophies are fundamental to well designed and effective e-learning environment. These fundamentals are determined by the decisions taken at various phases in the design of the system. Each of us has different learning styles and mechanisms; these should be supported through the use of sound pedagogical principles. However, a common problem has existed historically in the lack of uniformly accepted teaching and learning theories. Even looking back some 100 years at research in learning theory identifies a common deficiency in the understanding of how we humans interpret, process, store and recall information. Learning theory during this time has seen models move from behaviouristic theories, centred on new behavioural patterns being repeated until they become automatic (Gagne, 1987), early cognitive models focusing on problem solving and newer cognitive learning models based on information processing, to constructivist models focused on discovery learning.

Behaviourism

Behaviorism, as a learning theory, can be traced back to Aristotle, whose essay "Memory" focused on associations being made between events such as lightning and thunder. Other philosophers that followed Aristotle's thoughts are Hobbs, Hume, Brown, Bain and Ebbinghause (Mergel, 1998).

The theory of behaviorism concentrates on the study of overt behaviors that can be observed and measured (Good & Brophy, 1990). It views the mind as a "black box" in the sense that response to stimulus can be observed quantitatively, totally ignoring the possibility of thought processes occurring in the mind. Some key players in the development of the behaviorist theory were Pavlov, Watson, Thorndike and Skinner.

John B. Watson was the first psychologist to use Pavlov's ideas. Watson believed that humans are born with a few reflexes and the emotional reactions of love and rage. All other behavior is established through stimulus-response associations through conditioning. Watson is credited with forming the term "behaviorism".

Cognitive Theory

Cognitive theory is based on the following key concepts:

Schema - An internal knowledge structure. New information is compared to existing cognitive structures called "schema". Schema may be combined, extended or altered to accommodate new information.

Three-Stage Information Processing Model - input first enters a sensory register, then is processed in short-term memory, and then is transferred to long-term memory for storage and retrieval.

Meaningful Effects - Meaningful information is easier to learn and remember. (Good and Brophy, 1990). If a learner links relatively meaningless information with prior schema it will be easier to retain. (Wittrock, Marks, & Doctorow, 1975, in Good and Brophy, 1990)

Serial Position Effects - It is easier to remember items from the beginning or end of a list rather than those in the middle of the list, unless that item is distinctly different.

Practice Effects - Practicing or rehearsing improves retention especially when it is distributed practice. By distributing practices the learner associates the material with many different contexts rather than the one context afforded by mass practice.

Transfer Effects - The effects of prior learning on learning new tasks or material.

Interference Effects - Occurs when prior learning interferes with the learning of new material.

Organisation Effects - When a learner categorises input such as a grocery list, it is easier to remember.

Levels of Processing Effects - Words may be processed at a low-level sensory analysis of their physical characteristics to high-level semantic analysis of their meaning. (Craik and Lockhart, 1972, in Good and Brophy, 1990) The more deeply a word is processed the easier it will be to remember.

State Dependent Effects - If learning takes place within a certain context it will be easier to remember within that context rather than in a new context.

Mnemonic Effects - Mnemonics are strategies used by learners to organise relatively meaningless input into more meaningful images or semantic contexts. For example, the notes of a musical scale can be remembered by the rhyme: Every Good Boy Deserves Fruit.

Schema Effects - If information does not fit a person's schema it may be more difficult for them to remember and what they remember or how they conceive of it may also be affected by their prior schema.

Advance Organisers - advance organisers prepare the learner for the material they are about to learn. They are not simply outlines of the material, but are material that will enable the student to make sense out of the lesson.

Constructivism

Constructivism has its roots in ideas of discovery-learning and asserts that learners must "construct" their own knowledge and behaviors through undirected experiences. Constructivism is more a philosophical or theoretical approach to learning, than a specific model for the development of training program.

The basic tenets of constructivism are that:

- Knowledge is constructed from and shaped by experience.
- Students must take an active role and assume responsibility for their learning.
- Learning is a collaborative process and students create their own meaning from obtaining multiple perspectives.
- Learning should occur in a realistic setting.
- Learners should choose their own path through content and activities.
- Content should be presented holistically, not broken into separate smaller tasks.

The teacher's role should be that of facilitator. Students are encouraged to discover principles for themselves, whilst in active dialogue with the pedagogue. The teacher's task is to mediate information (called scaffolding) to be learned into an appropriate format applicable to the learner's level of understanding. The teacher organises the curriculum in such a manner so as to enable the student to continually build upon previously acquired knowledge. Good methods of structuring knowledge should result in learners simplifying, generating new hypotheses, and increasing the manipulation of information.

Constructivists believe that meaning is a function of how individuals understand their experiences. What we know is internally constructed by the individual rather than received from any external source. All Constructivists believe that the mind is essential in forming perspectives of the external world and that those perspectives are personal and individualistic (Jonassen, 1991 in Jonassen and Mayes, 1993).

Bloom developed a classification of levels of intellectual behaviour important in learning (Bloom 1956). The main idea of Bloom's taxonomy is that the knowledge that learners are required to know can be arranged in a hierarchy from less to more complex. Bloom identified six levels of learning demonstrated by:

Knowledge recall – comprehension – application of knowledge – analysis of data – – synthesis of data – evaluation of ideas or actions

With computer technology, a constructivist approach to training is easier than ever before. The calculation capabilities of computers enable complex quantitative simulations, which can be applied to simulated biological experiments or simulated business finances. CD & DVD-ROMs provide a rich media context for simulations. Realism is obtained with the use of audio, video, and more so now with virtual workspaces. The very nature of Web sites facilitates learner-controlled navigation of content with hyper-links. Examples of a constructivist e-learning approach include:

- Using patient treatment simulations to teach medicine to doctors, or other healthcare professionals
- Customer simulations to teach principles of sales or customer service
- Employee simulations to teach principles of management or supervision

Dual coding theory

Allan Paivio's (1971, 1991; Clark & Paivio, 1991) dual coding theory is relevant to multimedia information presentation and learning. According to Paivio, information is processed through one of two generally independent channels. One channel processes verbal information such as text or audio. The other channel processes nonverbal images such as illustrations and sounds in the environment. Both kinds of representational units are concrete, modality-specific (e.g., visual versus auditory versus sensory-motor) analogues rather than abstract, a modal structures. Paivio (1975) successively presented concrete items that included repeated pictures, repeated words, and picture-word combinations. People recalled more items that were successively presented as picture-word combinations compared to repeated pictures or repeated words.

Paivio believes that this effect resulted because people differentially encoded the successive picture-word combinations. People also recalled more successively repeated pictures than successively repeated words. Paivio believes that this is because people recall pictures better than words. This result is known as the picture superiority effect (Nelson, Reed, & Walling, 1976; Paivio, Rogers, & Smythe, 1968) and may be because pictures access semantic meaning more quickly and completely than words (Smith & Magee, 1980; Nelson, 1979). Paivio's dual coding theory emphasises that there are two modes of representation in memory-verbal and visual (this concept is also supported by Rollins and Thibadeau, 1973). Information is stored in the representation mode that most closely matches its presentation. The concept of dual coding is challenged by other investigators (e.g., Anderson, 1978; Anderson & Bower, 1973; Kieras, 1978; Kosslyn, 1980, 1981; Norman & Rumelhart, 1975; Pylyshn, 1973, 1981; Shepard, 1978) who believe that information is stored in a single, abstract memory.

Kozma's theory of learning with media

In Robert Kozma's theoretical framework, learning is "an active, constructive process whereby the learner strategically manages the available cognitive resources to create new knowledge by extracting information from the environment and integrating it with information already stored in memory" (Kozma, 1991, pp. 179-180). Many factors affect the ability to learn from media, including the construction of representations, the operations performed on the representations, characteristics of the medium, instructional designs, characteristics of learners, and characteristics of the learner's tasks.

According to Kozma, the symbol systems and information processing capabilities of a medium are important influences on the ability to learn the information presented by that medium. Symbol systems are the elements used to communicate via the medium. For example, a textual story uses words and sentences as symbols for objects and actions. Television uses pictures and audiolinguistic symbols. The symbol systems used by media influence the ability of a learner to process the information they represent. Some symbol systems are more closely matched with their representations in human memory. For example, pictorial symbols are a close match with images in memory. The information represented by these symbol systems is easier to learn than the information represented by symbol systems that are not closely matched by their representations in memory. Also, some symbol systems are better at representing certain information than other symbol systems. For example, a picture is better than a thousand words when it comes to constructing a mental model of a machine's operation. The symbol systems affect the mental skills needed to process the information and, hence, the learner's mental models.

Media most effectively help people to learn when the media's capabilities are used by the instructional method to provide representations or cognitive models that are important to the learning task that learners cannot do for themselves. For example, the stability of text and the ease with which a reader can slow reading speed or re-read a confusing sentence helps people learn. Television's unique ability to show motion helps people acquire motion-based information. The ability of a computer to transform numerical information into easier to understand graphical displays (e.g., bar charts) is a powerful learning aid. Kozma believes that the most outstanding aspect of learning from computerised multimedia is the ability to integrate the learning advantages for each of several media.

2.3.2 Instructional design

Until recently, many theorists considered instructional systems design and constructivism to be diametrically opposed. But now some similarities are becoming apparent between second generation instructional design and the approach of constructivists (Duffy & Jonassen, 1992).

If the two theories are not converging, they are at least viewed as compatible. Within the context of Gagne's events of instruction (Gagne 1987), there is certainly room for applying constructivist-inspired simulations and other experiential exercises, collaboration with peers in threaded discussions and chat rooms, and multiple paths to content and learning activities.

Distance education with its opportunities of using interactive, multimedia technologies affords the opportunity to cross learning styles and bring greater relevance to instruction. Jonassen et al. (1995) asks what professionals in the real world get paid to do? He states, "Few, if any are paid to memorise information and take examinations" Naidu (p. 21, 1994) describes the construction of an "instructional transaction" using the following five steps:

- Presentation of content,
- Activation of student learning,
- Assessing learning outcomes,
- Provision for feedback and remediation
- Evaluation of the impact of the instructional event.

This instructional transaction is quite a contrast to the memorise and test approach. The previously described learning theories and others applicable to e-learning are summarised in figure 2.1. Each of the models in figure 2.1 corresponds to a particular group of learning theories and therefore each has its specific focus relating to that learning theory. Likewise each of the theories in figure 2.1 has its strengths and weaknesses; however each of the theories may be combined ensuring a sound theoretical approach to e-learning. Nevertheless with regards the current state of e-learning, there is little evidence demonstrating how these theories are combined and subsequently applied to effective pedagogically centred e-learning or to frameworks / paradigms prescribing their uses to designers and practitioners (Beetham, Jones, & Gornall, 2001; Clegg, Hudson, & Steele, 2003, Lisewski & Joyce, 2003; Oliver, 2002). The shift from objectivist theory to constructivism is becoming more evident as mixed mode deliveries incorporate hypermedia components of instruction.

Theories	Main characteristics	Potential e-learning applications	Literature
Behaviourism	• Focuses on behaviour modification via stimulus-response pairs • Trial and error learning • Learning through association and reinforcement • Pedagogical focus is on control and adaptive response • Focus on observable outcomes	• Much of current e-learning development represents little more than transfer of didactic approaches online, the 'web page turning mentality' linked directly to assessment and feedback	Skinner Tennant
Cognitive	• Focus on internal cognitive structures; views learning as transformations in these cognitive structures • Focus on human development • Pedagogical focus is on the processing and transmission of information through communication, explanation, recombination, contrast, inference and problem solving • Useful for designing sequences of conceptual material which build on existing information structures	• Salomon's notion of distributed cognition (Salomon, 1993) could lead to a more shared knowledge structure between individual and surrounding information rich environment of resources and contacts • Development of intelligent and learning systems, and the notion of developmental personalised agents	Anderson Wenger Hutchins Piaget
Constructivist	• Focus on the processes by which learners build their own mental structures when interacting with an environment • Pedagogical focus is task-orientated • Favour hands-on, self-directed activities orientated towards design and discovery • Useful for structured learning environments, such as simulated worlds; construction of conceptual structures through engagement in self-directed tasks	• The concept of toolkits and other support systems which guide and inform users through a process of activities could be used to good effect to embed and enable constructivist principles • Access to resources and expertise offers the potential to develop more engaging and student-centred, active and authentic learning environments • Microworlds and simulations	Papert Duffy & Jonassen
Activity-based	• Focus on the structures of activities as historically constituted entities • Action through mediating artefacts within a framework of activity within a wider socio-cultural context of rules and community	• In the last decade there has been a shift from a focus on the information (and in particular content) aspects of ICT to an emphasis on communication, collaboration and understanding the factors which underpin the development of communities	Vygotsky, '34; Wertsch, 85; Engestrom, '87

Fig 2.1 (taken from Conole, Dyke, Oliver, Seale, 2004).

Figure 2.1 lists the main psychological models and their associated learning theories. Some advantages and disadvantages of each of the approaches are outlined as are the potential application into e-learning. For reference, literature from which each of the models originates is also included (taken from Conole, Dyke, Oliver, Seale, 2004).

Theories	Main characteristics	Potential e-learning applications	Literature
	• Pedagogical focus is on bridging the gap between historical state of an activity and the developmental stage of a person with respect to that activity e.g. current state of language use and child's ability to speak a language • The Zone of Proximal Development – the idea that assessing current ability gives limited insight into an individual's potential for development, which is better studied through examining their work alongside a more able peer	• In particular there has been a realisation that the development of content alone does not lead to more effective learning, and that there is a need to structure and foster learning environments to enable communities to develop • Networking capabilities of the web enable more diverse access to different forms of expertise and the potential for the development of different types of communities	
Socially situated learning	• Take social interactions into account and learning as social participation • Emphasis on interpersonal relationships involving imitation and modelling • Language as a tool for learning • and the joint construction of knowledge • Language has two functions: 1. As a communicative or cultural tool, used for sharing and jointly developing knowledge 2. As a psychological tool for organising our individual thoughts, for reasoning, planning, and reviewing our actions • Dialogue between tutor and student can be articulated into 12 levels of engagement – both external and internal • Knowledge is a matter of competences with respect to valued enterprise. Participating in the pursuit of this, i.e. active engagement • Meaning our ability to experience the world and our engagement with it as meaningful – is ultimately what learning is to produce	• Multiple forms asynchronous and synchronous communication offer the potential for more diverse and richer forms of dialogue and interaction between students and tutors and amongst peers, as well as the use of archive materials and resource for vicarious forms of learning • Different online communication tools and learning environments and social for a offer the potential for new forms of communities of practice or facilities to support and enhance existing communities	Mercer Vygotsky Laurillard Lave Wenger
Experiential	• Experience as foundation for learning • Learning as the transformation of experience into knowledge, skill, attitudes, values emotions • Reflection as a means of transforming experience	• Asynchronous communication offers new forms of discourse which is not time-bound and hence offers increased opportunity for reflection	Dewey Kolb Jarvis

Fig 2.1 con't … (taken from Conole, Dyke, Oliver, Seale, 2004).

Theories	Main characteristics	Potential e-learning applications	Literature
	• Problem base learning a focus: o Experience: Problem situation, identification and definition o Gather and reflecting on information o Theory formation and test in practice o Experience through Primary and Secondary o Reasoning and Reflection o Evaluation (Dewey, 1916)	• Archive and multiple forms of representation of different communications and experiences offer opportunities for reflection	
Systems theory	• Focus on organisational learning, or on modelling the development of learners in response to feedback	• New forms of distribution and storage, archiving and retrieval offer the potential for development of shared knowledge banks across organisations and forms of organisational distributed cognition • Models of learning account adaptation in response to both discursive and active feedback	Senge; Laurillard

Fig 2.1 con't ... (taken from Conole *et al*, 2004)

Cognitive theory is the dominant theory in instructional design and many of the instructional strategies advocated and utilised by behaviorists are also used by cognitivists, but for different reasons. For example, behaviorists assess learners to determine a starting point for instruction, while cognitivists look at the learner to determine their predisposition to learning (Ertmer & Newby, 1993). With this in mind, the practice of instructional design can be viewed from a behaviorist/cognitivist approach as opposed to a constructivist approach.

When designing from a behaviourist / cognitivist stance, the designer analyses the situation and sets a goal. Individual tasks are broken down and learning objectives are developed. Evaluation consists of determining whether the criteria for the objectives has been met. In this approach the designer decides what is important for the learner to know and attempts to transfer that knowledge to the learner. The learning package is somewhat of a closed system, since although it may allow for some branching and remediation, the learner is still confined to the designer's "world".

To design from a constructivist approach requires that the designer produces a product that is much more facilitative in nature than prescriptive. The content is not pre-specified, direction is determined by the learner and assessment is much more subjective because it does not depend on specific quantitative criteria, but rather the process and self-evaluation of the learner. The standard pencil-and-paper tests of mastery learning are not used in constructive design; instead, evaluation is based on notes, early drafts, final products and journals.

Because of the divergent, subjective nature of constructive learning, it is easier for a designer to work from the systems, and thus the objective approach to instructional design. That is not to say that classical instructional design techniques are better than constructive design, but it is easier, less time consuming and most likely less expensive to design within a "closed system" rather than an "open" one. Perhaps there is some truth in the statement that "Constructivism is a 'learning theory', more than a 'teaching approach'." (Wilkinson, 1995)

A solid foundation in learning theory is an essential element in the preparation of instructional system design professionals because it filters all dimensions of instructional system design (Shiffman, 1995). Depending on the learners and situation, different learning theories may apply. The instructional designer must understand the strengths and weaknesses of each learning theory to optimise their use in appropriate instructional design strategy. Recipes contained in ID theories may have value for novice designers (Wilson, 1997), who lack the experience and expertise of veteran designers. Theories are useful because they open our eyes to other possibilities and ways of seeing the world. Whether we realise it or not, the best design decisions are most certainly based on our knowledge of learning theories.

“We do not need to abandon the systems approach but we must modify it to accommodate constructivist values. We must allow circumstances surrounding the learning situation to help us decide which approach to learning is most appropriate. It is necessary to realise that some learning problems require highly prescriptive solutions, whereas others are more suited to learner control of the environment” (Schwier, 1995).

Jonassen and McAleese (1993) in ‘Manifesto for a Constructive Approach to Technology in Higher Education’ identified the following types of learning and matched them with what he believes to be appropriate learning theory approaches:

1. Introductory Learning - learners have very little directly transferable prior knowledge about a skill or content area. They are at the initial stages of schema assembly and integration. At this stage classical instructional design is most suitable because it is predetermined, constrained, sequential and criterion-referenced. The learner can develop some anchors for further exploration.

2. Advanced Knowledge Acquisition - follows introductory knowledge and precedes expert knowledge. At this point constructivist approaches may be introduced.

3. Expertise is the final stage of knowledge acquisition. In this stage the learner is able to make intelligent decisions within the learning environment. A constructivist approach would work well in this case.

Having pointed out the different levels of learning, Jonassen stresses that it is still important to consider the context before recommending any specific methodology.

Reigeluth's Elaboration Theory (Reigeluth, 1992) which organises instruction in increasing order of complexity and moves from prerequisite learning to learner control may work in the eclectic approach to instructional design, since the learner can be introduced to the main concepts of a course and then move on to more of a self directed study that is meaningful to them and their particular context.

After having compared and contrasted behaviorism, cognitivism and constructivism, Ertmer and Newby (1993) feel that the instructional approach used for novice learners may not be efficiently stimulating for a learner who is familiar with the content. They do not advocate one single learning theory, but stress that instructional strategy and content addressed depend on the level of the learners. Similar to Jonassen, they match learning theories with the content to be learned:
Ertmer and Newby (1993) believe that the strategies promoted by different learning theories overlap (the same strategy for a different reason) and that learning theory strategies are concentrated along different points of a continuum depending on the focus of the learning theory - the level of cognitive processing required. Ertmer and Newby's suggestion that theoretical strategies can complement the learner's level of task knowledge, allows the designer to make the best use of all available practical applications of the different learning theories. With this approach the designer is able to draw from a large number of strategies to meet a variety of learning situations.

Within e-learning the instructional designer's greatest role is that of "bridging" concepts between the two worlds of technology and education. This vital role ensures that a subject expert's concepts are properly developed by graphic designers, programmers and other members of the e-learning design/production team. However, instructional design models do not provide effective strategies for designing constructivist learning environments. With this being the case instructional design models have mainly been focused on behaviouristic approaches of sequencing Gagné's nine stage learning sequence is an example of this (Gagne, 1956).

Experienced instructional designers have, in the past, moved beyond the instructional design models by adapting and manipulating them using their past experience for a specific context. Unfortunately, the role of instructional design in e-learning has and still is often misunderstood, this is due to the perceived complexity of the process, the poor understanding of the pedagogical requirements of e-learning and diverse nature of e-learning itself (McNaught 2003). To a large degree, instructional design in e-learning is the process whereby learning, not technology, is kept at the centre of e-learning development (Siemens, 2002).

One can say that instructional design theory, in that it guides the practice of designers, is necessary and plays an important role in e-learning, both in corporate training departments and education institutions. However, it needs to change in many respects if it is to fulfil this role adequately. Whichever situation the instructional designer finds themselves in, they will require a thorough understanding of learning theories to enable them to provide the appropriate learning environment.

2.3.3 Multimedia instruction

Information can be represented in a number of ways, supporting different effects. Multimedia is the keyword in this concept. Multimedia can be defined in several ways depending on the approach (Guttormsen-Schär, S. & Krueger, H. 2000):

- A medium as context of a representation: diagrams or graphs, animation or videos, sound or audio and text

- A modality of communication or multisensory interaction: visual (eyes), auditory (hearing), haptic (touch), olfactory (smell) and gustatory (taste)

- A physical medium for storing information: optical media (CD's, DVD's), hard disks.

The role of multimedia in the instructional design of e-learning courseware cannot be understated. Its influence on the design process has been given increasing emphasis and much research has been undertaken in recent times investigating its effectiveness in enhancing the learning productivity. However, this field of study is still in its early stages and no definitive theoretical base has been established yet (Beccue, Villa & Whitley, 2001).

Several fundamental questions have and are being addressed. What makes effective multimedia instructional material; when does it work; for whom does it work and how does it works? Mayer (2001) states on this that "Multimedia instructional messages can be influenced by the instructional designer's conception of multimedia learning. When the instructional designer takes an information delivery view, the goal of the multimedia message is to deliver information. When the instructional designer takes a cognitive view, the goal of the multimedia message is to promote knowledge construction in the learner. This is accomplished not only by presenting relevant material in words and pictures, but also by helping the learner to process the presented material in meaningful ways. All multimedia messages deliver information to the learner, but they are not equally successful in promoting understanding" (Mayer, Moreno 2000). Investigating multimedia messages more closely Mayer (2001) formulated nine design principles to be implemented in light of his cognitive theory of multimedia learning:

i) Multimedia Principle – the first principle deals with the use of two modes of representation rather than one in explaining a concept, for example words and pictures rather than words alone.

Mayer and Clark (2003) call this the multimedia principle and show that better informational processing and transfer occurs from words and pictures rather than from words alone. This principle is consistent with Allan Paivio's theory of dual coding discussed in the previous chapter.

ii) Contiguity Principle – the second principle referred to as the contiguity principle or split-attention effect, deals with the positioning of various media elements being presented, for example placing printed words next to corresponding pictures. Clark and Mayer (2003) observed that students learn better when corresponding words and pictures are presented near rather than far from each other on a page or computer screen.

iii) Temporal Contiguity Principle -- refers to the synchronisation of the presented material and in summary states that students learn better when corresponding words and pictures are presented simultaneously rather than successively.

iv) Coherence Principle – deals with the learning environment. The principle states that students learn better when extraneous words, pictures and sounds are excluded rather than included.

v) Modality Principle – the modality principle refers to using both visual and auditory cognitive channels for the processing of information rather than a single channel. For example, using spoken words and animation is stated to produce more effective learning than using animation and on-screen text that depends on the single visual channel.

vi) Redundancy principle – this refers to situations where there is an overlap or replication of meaning and information between what the textual and pictorial representations convey where some of these representations become extraneous. For example it has been shown (Clark and Mayer 2003) that students learn better from animation and narration than from animation, narration and duplicate on-screen text.

vii) Individual difference principle – this principle deals with the learners knowledge and spatial abilities. It states that the design effects of a multimedia presentation have more of an influence on low knowledge learners rather than high-knowledge and for high-spatial learners rather than for low spatial learners. These distinctions arise since high knowledge learners, due to the well-grounded mental schemas they hold internally, are less needful of the effects of multimedia and contiguity. Learners who have high spatial ability hold onto visual images in the visual component of the working memory for longer therefore contiguity and multimedia have more benefits for high spatial learners.

viii) Personalisation principle – this principle states that students learn better, with regards problem solving transfer results, when verbal material is presented in a conversational style rather than in a formal third person style.

ix) Interactivity principle – the interactivity principle is the latest principle to be formulated and demonstrated. It states that multimedia messages result in better transfer performance when learners are able to control the pace of the learning material.

These principles should be employed and form the basis of multimedia design, applicable to multimedia learning and multimedia design for presentation. Moreover, when appropriately incorporated these principles augment existing instructional design strategies to produce interesting and meaningful multimedia learning materials. These guidelines serve as a basis for the design of the experimental electronic learning package outlined in chapter 3.0 and form a basis for further discussion in chapters 5 and 6.

Before multimedia became popular there was considerable debate to whether media influenced learning. This issue is still today unresolved. However it is important to distinguish between the debates of the media effects on learning and the multimedia effects on learning. The main research question for media effects on learning concerns whether learning is more effective when material is presented via one medium or another, for example via a computer or a text book. Whereas the research question of multimedia effects concerns whether learning is more effective when material is presented using two forms of representation or more, for example text or text and illustration. On one side of the debate arguments that certain media have unique potential to improve learning, such as in the learning of Newtonian mechanics in a computer based environment (Kozma, 1994), and on the other, Clark (1983) argued that media are "mere vehicles that deliver instruction that can not be separated from method effects" and concluded that "Media and their attributes have important influences on the cost or speed of learning but only the use of adequate instructional methods will influence learning" (Clark 1994). The underlying problem is that media research may be criticised on empirical, methodological, conceptual and theoretical grounds.

Firstly, media research has a disappointing history of inconclusive empirical studies (Clark & Salomon 1986; Mayer 1997). Secondly, methodological inconsistencies in the instructional messages where it is not possible to distinguish whether the differences in what was learnt is caused by the media or by the content and study conditions; for example the difference of interpretation of a narrated text, with it stresses and nuances and that of a printed text. Thirdly, learning depends on the instructional quality of the message rather then the media itself. It is possible to design effective text based material and equally effective computer based material. It is also possible to design instructionally poor text and computer based material. Fourthly, the learning theory of electronic media relies on is an out dated learning model. Learning from a media perspective fails to take into account constructivist views of learning and solely depends on a behaviourist model of information delivery. Lastly, there is a great deal of codependence among media components of electronic learning that complicate empirical research and add confusion to debates.

There is a growing body of evidence that the "multi" in multimedia can lead to poorly designed instruction that impedes learning. For example, Mousavi, Low, and Sweller (1995) found that presenting instruction in both auditory and visual modes can cause a "split-attention" effect where students have to divide their attention across multiple inputs resulting in reduced processing. Several studies have found that adding audio instructions to visual text and/or graphics does not increase learning (Barron & Atkins, 1994; Beccue, Vila, & Whitley, 2001). Further, Kalyuga and his associates reported that presenting identical information simultaneously in audio and visual form can have a negative effect on learning. These researchers explained their findings in terms of cognitive load theory which postulates that working memory can be overloaded by redundant information (Kalyuga, Chandler, & Sweller, 1999; Kalyuga, 2000; Kalyuga, Chandler, & Sweller, 2001a).

Many studies have been conducted to answer the fundamental question of whether multimedia effects learning. Mayers (2001) research reports on nine empirical experiments that all support (median percentage gain of 89 and effect size of 1.50) the view that learners perform significantly better in retention and problem solving transfer tests when pictures and words are used rather then words alone. Liao's (1998) meta-analysis reviewed 35 studies and concluded that multimedia instruction is superior to traditional instruction, however, notably 10 out of the 35 studies showed the opposite. A subsequent meta-analysis of 46 studies by Liao (1999) confirmed the overall positive effect of multimedia on student achievement but found that this depended on what type of instructions was being compared. Further a review by Dillon & Gabbard (1998) where 30 experimental studies on the effects of multimedia showed little evidence that it improves comprehension. These contrasting findings suggest that the great number of variables are involved with studying the effects of multimedia instruction and that these are difficult to control in experimentations. These variables lead to contradictory results and the unanswered question of "what factors truly affect the diverse outcomes for different types of instructions."(Liao 1999). Research on how people process multimedia information has also many associated complexities. For example people have better short-term recall of auditory than of visual information (Penney 1989) and benefit from narration to get instruction from animation, (Mayer & Anderson 1991) but it has been observed that learners will read text on screen if presented simultaneously (Grimes 1990). With regards audio-video redundancy Lang (1995) states "Forty years of research has yielded a hodgepodge of contradictory conclusions" with half the studies showing that redundant audio and video channels improve retention of information and half showing redundancy impedes retention. Again, it is clear that many contingent factors are involved. One such contingency is whether or not the redundant information allows dual-coding of information in both propositional and visual form (Dubois & Vial, 2000). Numerous studies confirm that human memory and cognition is based on the separate coding of imagery and verbal information (Paivio, 1991; Mayer & Sims, 1994; Mayer & Moreno, 1998).

In an attempt to address the contradictory findings riddled within multimedia literature which appear to mainly arise from methodological discrepancies in uncontrollable variables which influence the variable being investigated, Hede (2002) has devised an integrated model, figure 2.2. The model is complicated but needs to be due to the large number of variables needing to be considered. It is more classificatory and descriptive than explanatory and predictive. "The model is compatible with a holistic view of learning as a complex psycho-social interaction between the learner and the instructional designer, a process occurring within a learning environment which includes the delivery media and their attributes" (Kozma, 1994 in Hede 2002). "The problem of analysing the effects of multimedia on learning is due to their being a large number of variables that are difficult, if not impossible, to isolate in an experimental procedure or single meta-analysis" (McNeil & Nelson, 1991). These researchers attempted to code 79 independent variables across the different studies but still concluded that they failed to explain much of the variance.

An integrated model of multimedia effects on learning

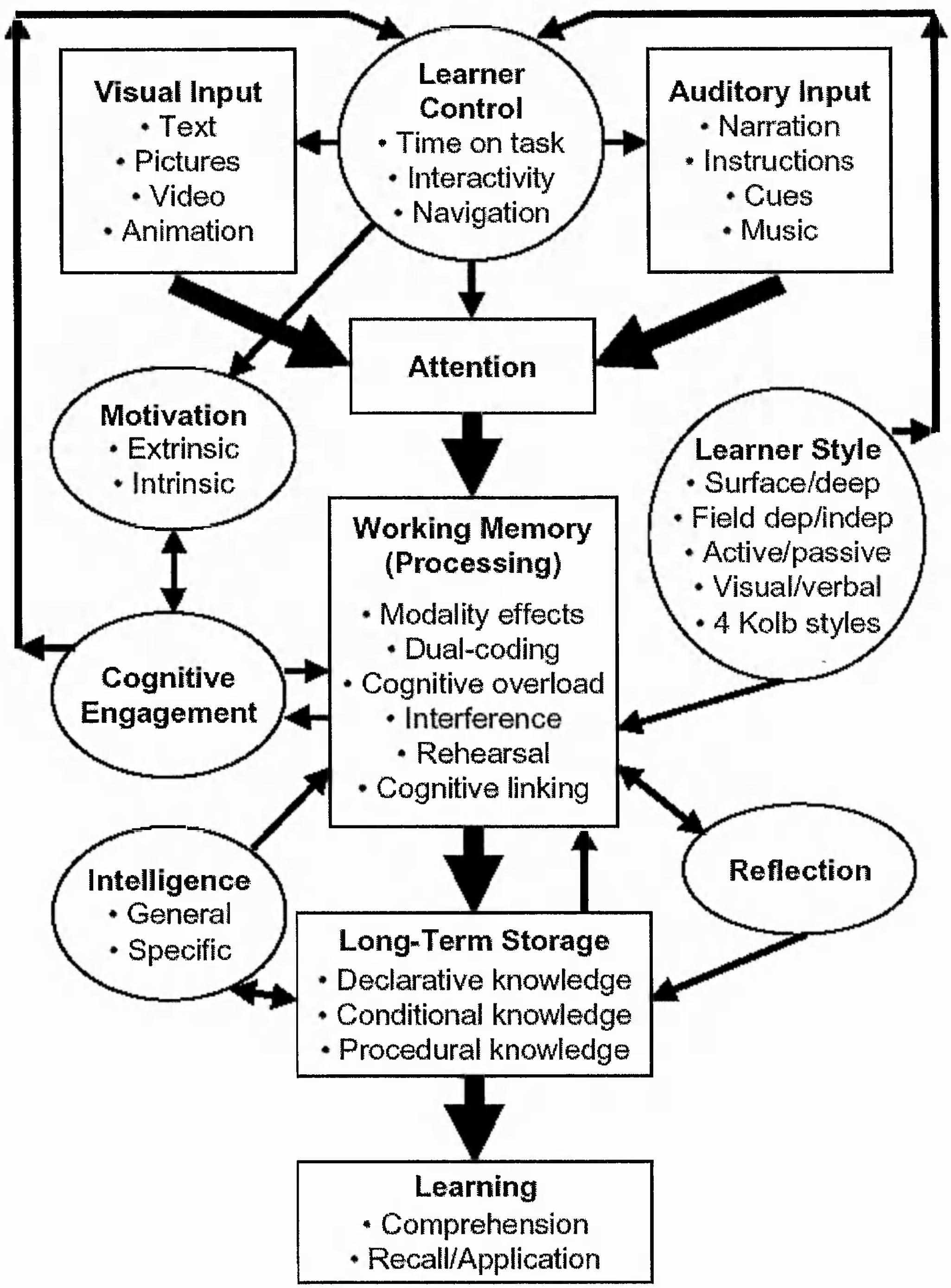


Figure 2.2 Model devised by Hede (2002) illustrating the inter-connections between the numerous variable associated with multimedia learning. The model aims to address the contradictory findings riddled within multimedia literature (after Hede 2002).

2.3.4 Summary

With e-learning being very much in vogue over the last few years and subsequently drawing large amounts of interest from groups of various backgrounds, there has been a rush to implement new forms of these learning technologies with the aim of capitalising on current hype and trends. This has come at the cost of ignoring fundamentally important learning principles and theories within such implementations and developments with the area suffering from contradictory research.

Firstly, and most notably, there is the unresolved debate surrounding on the effects of type of media on learning, its co-dependence on other factors, and more recently the effects of multimedia on learning. This has impacted in the lack of translation into sound prescribed instructional design methods. As a result, much confusion exists within the field and needs addressing. There is little evidence that multiple learning theories are being used in pedagogically centred e-learning and only some recent evidence of this problem being addressed (Hede 2002; Mayer 2001; Mayer 2005;). Other important issues include 'scaffolding' and 'anchoring' of the learners learning and to what degree regulation should occur. Also being raised is an important issue of context, in that different subject areas, and learners, are more suited to different learning theories and instructional messages.

Against this background the experimental phase of this research aims to compare a traditional learning methodology against a more multi-modal constructivist approach, with the view of incorporating elements into a more holistic socially active learning environment. The importance of instructional design being grounded on learning theories and the importance of selecting appropriate methodologies to suit individual learner is highlighted as a key factor, and discussed.

2.4 Technical Review of E-Learning

This section aims at reviewing the numerous trends and technologies that have been used and are currently being used in an e-learning context. Historically, trends have been centred on a distance learning approach that utilised available technologies as they developed and aimed to enhance the learning programmes.

To make distance learning possible some form of communication is required to connect the learner and the teacher/trainer. According to Nipper (1989) distance learning can be divided into three generations:

First generation distance learning appeared in the late 1800's, and consistes of paper texts correspondence that are sent through the post to the student where they learn by themselves in isolation.

Second generation distance learning, also known as the 'industrialised multimedia distance education', appeared in the 1960's. Public broadcasting technology had developed and become an accepted mode of delivery by learners. Distance learning programs subsequently took advantage of these new modes of delivery and matured to include television and radio broadcasting, and the use of video/audio cassettes.

In recent times technology has progressed one step further to the so called 'third generation of distance learning'. Development of digital technologies has enabled distance learners to freely interact with other learners on similar programs. Use of the internet has not only unlocked a wealth of information to the learner, it has also enabled learners to asynchronously communicate with each other through the use of email, forums, and organisational custom created supportive communities. This movement has given rise to numerous trends and technologies that are enhancing learning, creating new paradigms for learning and causing a re-organising of institutions approaches to learning/training and education.

Tutoring systems

Tutoring systems are most commonly associated with computer based training (CBT). They descend directly from linear programs developed for computer aided instruction and have been the main form of electronic learning since the 1950's. CBT systems bring images of mundane instructional materials that other than being incorporated on a computer system, feature little advantages over traditional learning material. Tutoring programs have advanced somewhat throughout the years and although many constructivists would argue the contrary, tutoring systems have their place in facilitating in an e-learning environment.

Programs typically open with an introductory section that overviews the purpose and nature of the program, before beginning a cycle. Information is presented and elaborated. It is common for a response to be then asked of the user, before proceeding to the next cycle. The response is judged and feedback given. At the end of each of the cycles the program performs a sequencing decision determining what information should be passed on to the next cycle. The programs are designed to engage the student in a dialogue and take them through a series of pre-programmed steps. The program ends with a summary or closing remarks. Tests are often incorporated to determine if instructional goals have been met and the program may not allow the user to progress to the next section until the test has been completed to a satisfactory standard.

Tutoring systems cover a wide variety of learning applications and are commonly found in academic environments and also in the work place facilitating the training of employees. Examples of such learning systems are work place health and safety education; performing specific tasks in ‘how to’ packages; software instruction; programs are typically delivered on distributable media.

Tutoring systems are based on objectivistic learning philosophy in that the facts speak for themselves and that knowledge exists independently of the learner. Successful tutoring systems teach students the knowledge and skills used to fulfil tangible tasks, for example analysing information or diagnosing a problem. The programs are mainly concerned with presenting the information and guiding the learner. This type of system is particularly effective for users that are unfamiliar with the learning material or unsure with the computer systems on which the program is being deployed. The sequential structure of information is familiar to most in so far as it resembles the structure of more traditional means of learning, i.e. text books, instruction manuals. The underlying negative is that users have little control over the entire system and learning process.

Intelligent tutoring systems (ITS) model the users’ perceptions, learning strategy and knowledge level. The system uses artificial intelligence component to integrate the user model into the strategy of the intelligent tutoring system. A student learns form an ITS by solving problems. The way in which a problem is solved by a user is analysed by the system based on the difference between the users’ answer and the model answer. After giving feedback the system re-evaluates the user model, updates as necessary and continues on to the next cycle. As the system is evaluating the user model it also is considering which part of the program to deliver next and how to present the material. Figure 2.3 illustrates the process.

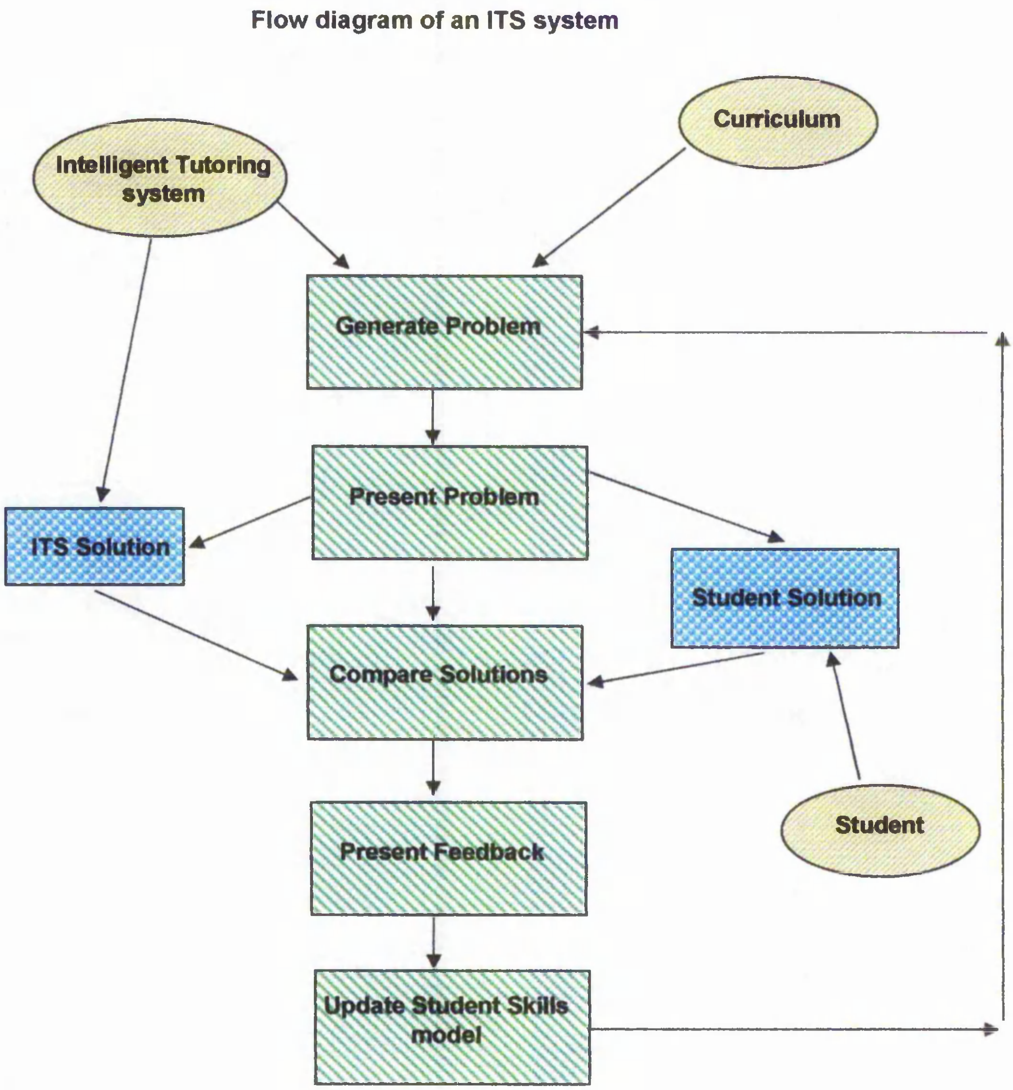


Figure 2.3 the cyclic processes involved within a typical intelligent tutoring system (ITS).

Adaptive tutoring systems and adaptive hypermedia systems are relatively new research directions in the area of adaptive and user-model based interfaces. The goal of adaptivity has featured in the design of intelligent tutoring systems for a longer period and are a strong component of whether a system is truly intelligent or not. Adaptive systems try to deal with the fact that the users are individuals and focus on the capability of altering the content or presentation of hypertext or hypermedia on the basis of dynamic understanding of the individualistic characteristics of the user.

The following characteristics are associated with adaptive hypermedia systems:

- Be based on hypertext or hypermedia;
- Have an explicit user-model which records some features of the individual user;
- Have a domain model, which is a set of relationships between knowledge elements in the information space; and
- Be capable of modifying some visible or functional part of the system on the basis of information contained in the user-model.

Adaptive systems are learner centred which is a major pre-requisite for designing effective e-learning. There have been continuous calls for more tools, applications and systems to be created with sound pedagogical working rather then the repetition of over hyped 'killer' application (Norman 1993; Landauer 1995; Mayer 2001). One of the main elements of a sound pedagogical underpinning of e-learning material is suiting the material, style of presentation and type of instruction to the students' personal learning style. Learning styles and ways of accommodating them has been research significantly in the traditional classroom setting however, currently there is much less research of the application of learning styles in e-learning.

Most adaptive educational systems take into account learner features like goals/tasks, knowledge, background, hyperspace experience, preferences and interests (Brusilovsky, 2001). Less attention has been paid to the different ways in which learners perceive, interpret and process information. Recent researches (Gilbert, J.E. and Han, C.Y. (1999); Grigoriadou, M., Papanikolaou, K, Kornilakis, H. and Magoulas, (2001); Kwok, M. and Jones, C (1985);) are attempting to address this and integrate learning styles in the design of their adaptive applications.

One such example is the AHA! project (Adaptive Hypermedia for All) (http://www.nlnet.nl/project/aha/). AHA has developed an open source adaptive engine that facilitates the extension of Web servers with transparent adaptive functionality. The engine uses Java Servlets that may be written in two formats: an XML format in which real page content is transparent to the system or XHTML format where both HTML and AHA! is combined. AHA!

may be used with any content presentation/layout application and concerns itself with the severing of HTML pages with conditionally included page fragments; links and anchors that are conditionally coloured or hidden. Adaptation is based on a domain model, a user model and an adaptation model using concepts, pages, fragments and condition rules. AHA! is centred on maintaining a user model and the generation of adaptive html regardless of actual content or layout. The project has concluded with the release of all research with regards the project, the engine and source code and tutorials for using and implementing the engine.

Drill and practice

Another methodology and an often used trend in electronic learning are drill programs. Drills, like tutorials are based on a more objectivist learning philosophy. In drill programs the computer system acts as a tester and learner is required to give answers to those questions. They are typically preceded by instructional methodologies, a tutorial or simulation program, or simply reading a text book or attending a lecture, this provides the learner with the information on the subject after which a drill may be performed.

The strategy promotes learning by continuous practice and rewarding correct answers. Drills receive a lot of criticism some of which is deserved, claiming that drills do not take full advantage of computer systems capabilities, and some of which is not. This methodology concerns itself with the practice stage of instruction, one that is extremely important and is especially effective in learning fluency. This is type of methodology is required, for example, in basic skills maths and science, foreign languages, spelling and vocabulary; here learning relies on memorisation of material rather then deep understanding. Drills are not to be avoided due to their simplistic nature or due to efforts being placed on other more sophisticated types of learning programs, but should be identified for its strengths and developed to be of better quality (Alessi S. M. & Trollip S. R 2001).

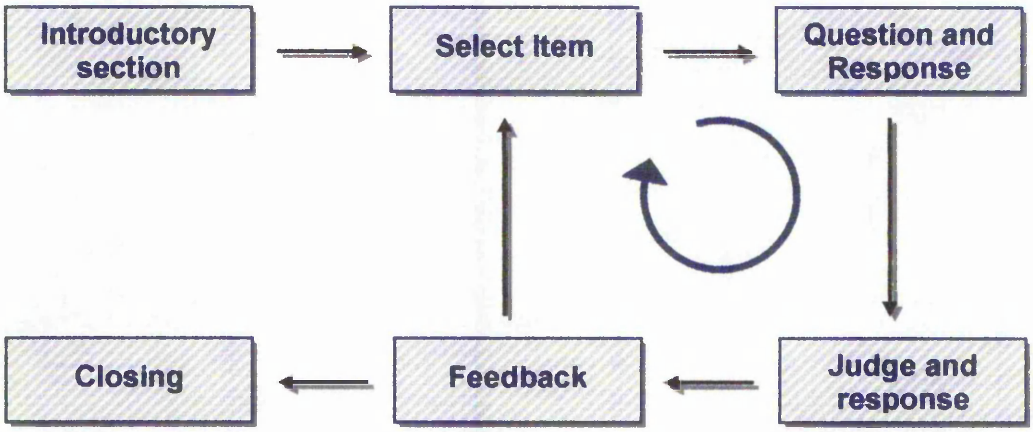


Figure 2.4 the cyclic nature and general structure of a typical drill type system (after Alessi S. M. & Trollip S. R 2001).

Drills like tutorials have a linear structure; figure 2.4 illustrates this general structure. Drills commence with an introduction followed by a cycle that is repeated a number of times. The following actions typically take place in a drill:

- An item is selected by the learner.
- The item is then displayed to the learner.
- The learner responds to the information being displayed.
- The drill program judges the response of the learner.
- The learner finally receives feedback about the response.

The procedure differs from tutorials in that there is usually no information presented to the learner, in drills an item is selected rather than presented. Drills mainly follow the above basic procedure, however, many variations exist. Major criticisms of drills are with regards their quality. Most do not incorporate sound instructional principles and do not collect valuable information about the learner.

2.4.1 Interactive environments

Hypertext and hypermedia (multimedia) systems

Hypertext organises text as a network of nodes connected by links (hyperlinks). This linking capability allows a nonlinear organisation of the information. The links let users navigate through the hypertext data set with a pointing device (mouse, or finger on a touch screen). Hypermedia refers to a multimedia style of hypertext in which nodes may contain graphics, audio, video, and other items in addition to text. From a pedagogical point of view, hypertext/media can support knowledge acquisition in a constructivistic way. The hyper structure lets students explore an environment for information acquisition according to individual strategies and needs. The benefits are comparable to those of a simulation.

Because users can explore the system freely, this feature is at the same time hypermedia's greatest disadvantage. Nonlinear navigation can easily result in a lost in hyperspace feeling. Users do not know where they are in the system and may forget or fail to register how they got there.

This inhibits learning and full use of the knowledge contained in the system. The student expends cognitive effort to explore the system rather than on the learning material itself. This navigation problem still impedes applying such systems to education.

Many Web browsers and search engines are good examples of hypertext and hypermedia applications. The home page of a search engine offers hypertext as the starting point of a more structured search method. Also, pictures, icons, and animations frequently serve as eye catchers which, when selected, open new information windows, dialogue boxes, or pages.

In recent years, the streaming service such as the video on demand (VOD) is becoming ubiquitous to our lives. Proprietary streaming technologies such as 'Advanced Systems Format' (ASF) of Microsoft (Microsoft ASF, 2002) and 'Real Movie' (RM) of Real Networks (Real Networks, 2002) win the majority of the market share. However, these proprietary technologies inherit significant limitations such as proprietary data formats, data access protocols, media server and player programs, underlying network supports, etc., which forces them to not easily inter-operate with other technologies. For overcoming the proprietary limitations of these technologies, standardised technologies such as the Synchronised Multimedia Integration Language (SMIL) (W3C, 2001) of the World Wide Web Consortium (W3C) and MPEG-4 (MPEG.ORG, 2002) of the MPEG forum are proposed to provide more flexibilities on media data formats, access protocols between media servers and players, underlying communication networks, etc.

With these standards, structured and complex multimedia documents that consist of media objects of various types can be created, shared and maintained much more easily in the distributed network environment. For example, the SMIL document can be composed of several streaming audio segments/video clips, non-streaming images/texts/graphics, and other types of media objects that may be stored at different remote media servers. The SMIL player first downloads the SMIL document from the Web server and then parses its content to retrieve the temporal and spatial relationships for synchronous presentations of the SMIL document in real-time. Some of SMIL's other advantages are as follows:

- SMIL is faster and easier than JavaScript / Dynamic HTML when it comes to programming animation and mouse events.
- Soon be adopted as a universal Web standard.
- Easy to use and learn.
- SMIL is already supported in IE, RealPlayer, Windows Media Player, and Adobe's SVG plug-in.
- SMIL will run even if users have JavaScript turned off in their browsers.
- It is possible to perform complex actions that JavaScript / DHTML can not handle.
- SMIL animations are faster than Flash animations for some projects.

Microsoft calls the HTML+SMIL support in Internet Explorer "HTML+TIME", but little difference exists between how HTML+SMIL and Microsoft's version are implemented. The current release of Internet Explorer supports the synchronisation and timing module, animation, media object, and SMIL Integration module portions of the specification

Simulation based systems

An interactive simulation can demonstrate the conditions of actions and events in the real world. It is a flexible learning tool, and from a pedagogical point of view, supports a constructivistic learning philosophy. With simulations, developers attempt to provide a rich environment in which students can explore freely. Such an environment places more initiative and control in the hands of the students and additionally makes possible several different strategic approaches. It may also engage two or more students simultaneously in a learning session.

Simulations prove useful for learning the contents of procedural, causal nature such as laws of economics and ecology, or chemical and physical processes. Procedural knowledge contains information about events or actions and the conditions under which they occur. In a simulation, the students can interactively experience the conditions of such events. By exploring the simulation, students can generate hypotheses as necessary precursors to expanding their own intuitions. Simulation-based systems induces intuitive knowledge representations from the perspective of the expert (Guttormsen-Schär & Krueger 2000) do however leave the learner to their own devises. This can leave a more challenged learner susceptible to becoming lost in the degree of freedom.

Simulations, which may include animations, video, and images, or may be purely text-based, allow learners to explore roles that they otherwise could not, all in a safe, encouraging setting. Technology can facilitate connections between players, making games more dynamic and interesting.

Educational Gaming

Computers and games have been and are typically associated with one another; games themselves are as old as mankind. Social or solitary, simple or complex, collaborative or competitive, games give us an opportunity to exercise the sense of play. Children are typically able to learn games before they can talk; an example to of this is one of the simplest games 'a-peek-a-boo'. In terms of education games are engaging and adaptable to almost any subject. They are particularly useful for teaching cause and effect relationships. Experience, knowledge and skills obtained from games are retained for a longer periods then traditional forms of learning due to the constructive style of learning. Interactivity, collaboration with other and increased motivation all add to create a pleasurable learning experience which is not directly associated with working. This approach therefore typically sees learners spending much longer periods on this type of learning as compared to more traditional forms. Games also allow for the practice of new skills learnt and further evaluation and recognition of progress has a positive influence on motivating the learner.

While technology is not essential for the creating of educational games, technology and games are being combined is ever more interesting ways. Technologies can facilitate the connections between players making games more dynamic and interesting. Cooperative play lends another dimension to learning through games. Using technology in games, as in simulations, can create an environment that would otherwise be financial or physically be unrealistic to experience or participate in.

In a learning and training setting using educational games, for maximum success, the motivational element of the game should run parallel to the overall motivation strategy of the learning or training programme. The game or games included in the programme should have its instructional and educational value aligned with the objectives of the overall programme or course. There is however little merit to using games as a reward for completing learning objectives exterior to the games themselves.

Game technologies have struggled for some time to be taken seriously in the educational arena. Games are seen to emphasise entertainment, fun and pleasure and often seen to include repetitive challenges. These factors until recently have been deemed to be a distraction from the more serious computer aided learning technologies. Despite Malone's (1980) early research in the area and Turkle's (1984) identification of the potential role of games in supporting learning, it is only relatively recently that educational research has been encouraged, supported and sustained in this and related areas, for example, mobile gaming (Facer, K. et al 2004). Research that has taken place increasingly points towards the potential of computer games to offer opportunities to not only learn through experiences but to develop meta-level reflections on the strategies for learning (Gee 2003; Kirriemuir & McFarlane 2003; Squire 2003). Other examples of the recent research in educational gaming include Games-to-Teach (MIT at http://educationarcade.mit.edu/gtt/), Labwebs' Room 130 (available at http://labweb.education.wisc.edu/room130/index.htm) and Unification: Alternate reality gaming (available at www.unification.com).

2.4.2 Collaborative learning, learning communities and social learning networks

"Just placing students in groups does not guarantee collaboration... The incentive to collaborate has to be structured within the groups." Kreijns, Kirschner and Jochems (2003)

"Collaborative learning environments, whether virtual or temporal, are developed on the assumption that knowledge is a complex entity that is shaped by social context, not a simple product to be transmitted or shared." (Daniel 2003).

Collaborative learning rather obviously implies learning with others which may be more effective than learning on one's own, but this is not in itself a particularly exciting idea. Collaborative learning becomes powerful and exciting when it occurs in the context of a 'community of practice' or 'learning community'.

A community of practice could be formed by a well-defined small group (such as a research group at a university) or a large unstructured collective (such as people involved in the discipline and profession of education) or anything in between. Such communities have, over time, developed a certain level of trust and evolved sets of assumptions, practices, hierarchies, and projects which enable their members to work together. In the real world we learn most in the process of becoming part of such a community and of contributing to what it is doing.

Communities of practice differ in how effective they are as learning communities. Some provide few opportunities for novices to gain entry and start making a worthwhile contribution to the community's work; others have many different ways for people to become involved at different levels of competence. Some blindly follow long-established traditions; others are more reflective about their own status and practices as a learning community.

Social learning networks allow for communication between the following:

- Learners themselves – achieved using asynchronous communication via a forum and a 'frequently asked question' database. Additionally a dynamically updateable email address book of learners currently making use of the system shall be made available.

- Moderator / mediator and learners – Communication between the moderator and learners may be in the form of emails and forum based communication.

- Designer, mediator and learners – aid in the development of the learning module, a problems / suggestions section typically is added into the forum to be used as a feedback mechanism for problem reporting, suggesting new ideas, evaluation and communicating with the designer of the learning system.

Aiding in these communications and fulfilling crucial organisational functions Virtual learning environments (VLE's) and Managed learning environments (MLE's) create portals that facilitate communication and collaborative working between all the above groups.

VLE's and MLE's

VLE's and MLE's are software products that use a virtual space to create an arena for collaborative learning, administration of courses, communication boards for communication between tutors and students, delivery of learning resources and material, assessment, management and tracking of students all of which is offered in a consistent layout and feel to the area. VLE's and MLE's aim to support learning and teaching activities across intranets and the internet allowing educators to create resources quickly and without the need to develop in depth technical skills. MLE's usually incorporate most features of VLE's however MLE's also include and interact with a range of information systems, such as student records systems and financial systems allowing for more dynamic features to be incorporated into one area.

Benefits of online VLE's / MLE's include:

- Simpler administration of large numbers of learners.

- Learner centred strategy may be adopted. The virtual learning environment maybe used to provide different learning opportunities for individual learners.

- Student tools allowing students to upload and share files as well as communicate with each other, upload course work, other 'drop boxes' shared electronic diaries and calendars.

- Structured delivery of information supported by a standard navigation toolbar.

Disadavantages of VLE's / MLE's include:

- Can become a 'dumping ground' for materials not designed to be delivered online.

- Copyright and IPR of materials need to be considered.

- Off campus access to hardware and networks can be problematic for both tutors and learners. Accessibility to online materials for impaired individuals needs addressing.

- Independent learning needs to be guided and supported with appropriate training for both tutors and students.

- Interoperability problems between different information systems and platforms.

A short case study of this university can highlight the effectiveness of VLE / MLE's. There are many commercial packages available to fully implement a VLE in an institution. The two most common packages are 'Blackboard' (www.blackboard.com) and WebCT (www.webct.com). The Nottingham Trent University chose to build it's own VLE using Microsoft Exchange as the back bone of the system. The advantages of a proprietary MLE such as this is the increase in flexibility of the MLE to integrate more easily with current information systems that use a similar architecture, and also advantages in reducing costs. The Nottingham Trent Universities MLE, the Virtual Learning Portal (VLP), was first introduced in the 2002/03 academic year and received a warm welcome from students and lecturers whom quickly became familiar with the simple to use interface and powerful functionality that was offered. The statistics show that during 2002/03 12,000 users logged into the VLP with a total of ½ million separate logins and 140GB of downloaded data. During 2003/04 this increased to 22,500 users with 1.5 million separate logins and 1000GB of downloaded data. Again during 2004/05 a significant increase was seen with 25,500 users logging in to the system, 3.3 million separate logins and 2100GB of data downloaded. This progressive increase in use of the VLP over the three year period illustrates the effectiveness and popularity of such virtual and managed learning environments.

There are many different collaborative methodologies that have emerged utilising the internet as a means of collaboration. Some of the older and more familiar include:

- E-mail – ubiquitous and very flexible, but difficult to build coherence.

- Discussion groups – simplifies broadcasting e-mails to a group, but volume can get overwhelming and lack of coherence remains a problem.

- Threaded discussions – supposedly allows for greater coherence than plain discussion lists (by linking different threads of the group conversation), but cumbersome and time consuming to use in practice.

- File sharing by e-mail – allows for different people to work on a common document, but version control very difficult, especially for larger groups.

- File sharing via a network – better version control (depending on the system), but difficult to set up.

Recent developments of such collaborative methodologies include Wiki's, Web Blogs, Really Simple Syndication and electronic-Portfolios:

Wikis

Wiki is Hawaiian for quick. It is also a software tool that allows users to create and edit hyperlinked Web pages (HTML) for viewing in a Web browser. Wikis typically use simple syntax to enable users to easily create new pages and hyperlink without having to learn HTML tagging. In addition to the open source programs there are many commercial copies of such programs and additionally some 'wiki farms' where you set up your own wiki online without needing your own sever. Wikis are typically used as personal or collaborative content management systems as they allow users to rapidly create, maintain and expand an intricately interlinked network of pages on a particular topic - e.g., a hypertext manual for a particular system or programme. There are numerous examples of Wikis online the best known is Wikipedia (available at http://en.wikipedia.org/wiki/Main_Page). This is a very useful online encyclopedia which everyone has the right to contribute to. It is the world's largest wiki website containing more than 200,000 articles (December 2004).

There are many free open source wiki software implementations a few of these are

- UseModWiki (available at http://www.usemod.com/cgi-bin/wiki.pl?UseModWiki) has a reputation for being particularly easy to install and with a good balance between features and ease of use.

- Tiki (available at http://tikiwiki.org/) is an open-source wiki-based content management system.

- The system running Wikipedia is available for free download, this tool is particularly useful as in incorporates lots of features and scalability.

Web blogs

"One of the most successful forms of e-learning is collaborative learning done online through social interactive discussion. Weblogs build off of this successful model as a dynamic form of e-learning content and an engaging e-learning experience" (Paul Stacey 2003).

Blogs or weblogs take many forms, but a blog typically resembles an online diary - except that entries need not be of a personal nature and that there are usually many links to other online content (e.g. other blogs). Collaboration happens through blogs in the following ways:

- Many blogs have a facility for readers to post comments.

- Some blogs are co-authored.

- Many blogs have a prominent list of links to 'like-minded' blogs also called blog-rolls.

- Many blogs have a facility for syndicating their content to other blogs through automated systems such as Really Simple Syndication, for details on RSS see section on Syndication).

- There is a strong trend of blogs commenting on (or re-circulating) material from other blogs.

Different blogging tools differ in how well they support these different forms of collaboration - e.g., LiveJournal (available at http://www.livejournal.com/) is effective at encouraging the creation of small circles of friendly blogs. There is also a generic tool named Trackback (Mena & Trott, B. 2003) that facilitates such connections.

'Podcasting' and 'Video blogging' are similar to a weblog, however, these use audio / video files and audio / video streams instead of text. A podcast is an internet-based radio show using uploaded MP3 audio file to a website from where it can be downloaded and then listened to on demand. Podcasting provides for a range of different activities from talk and music shows, interviews, story telling and audio books, tutorials and instructions, giving directions and sharing information to providing commentaries on events. Video blogging replaces audio files with video files.

Syndication

Syndication, and the syndication protocol known as RSS (known as "rich site summary", "really simple syndication" or "Resource Definition Framework (RDF) site summary"), has become a very popular adjunct of weblogs. RSS allows blog authors (or anybody else) to distribute their new content to topic-focussed "channels" and for blog readers to "subscribe" to such channels. In practice this means that I can, for example, stay up to date with what a whole range of blog authors have been saying about e.g. collaborative learning, without the hassle of having to read each author's blog (including their musings on all sorts of topics I am not interested in). RSS is a very simple XML mark-up system, so it is relatively easy to make one's content available in RSS-encoded form (i.e. to create an "RSS feed"). To read RSS-encoded content, one can either simply visit a website which aggregates RSS feeds relating to a topic one is interested in or use a desktop program such as AmphetaDesk or FeedReader.

In the context of collaborative learning, syndication is perhaps most interesting because it facilitates (as is illustrated in blogging) the formation of smaller interest groups within a larger distributed system, with each participant in the system typically belonging to several interest groups - so that there is much overlap among groups, but no single large group.

The main downside to RSS is the draining of bandwidth due to RSS readers regularly checking subscribed feeds for new content. This can severally hamper a server's performance on popular feeds.

e-Portfolios

Batson (2003) defines an e-portfolio system as "a dynamic Web site that interfaces with a database of student work artifacts". E-Portfolios work like a repository except that it is specifically focused on products created by students. Portfolio-based learning and evaluation is usually concerned with individual students' creations, but collaborative portfolios do exist. Even where individual products are emphasised, students are often collaboratively involved in commenting on and rating one another's products. The ePortfolio research and development community (ERADC) has a list of e-portfolio systems. A free, open-source portfolio system that has been developed over a period of six years can be downloaded from the Open Source Portfolio Initiative (OSPI) with interesting demos at http://eportfolio.d.umn.edu/. The Electronic Portfolio Consortium, or ePortConsortium, is the collaboration of higher education and IT institutions working to define, design, and develop electronic portfolio software environment and management systems.

2.4.3 Mobile learning

One of the more recent trends of technology enabled learning has followed suit with cultural changes in the use of technology on the move. Mobile technologies and other recent technological developments are increasingly being employed in everyday life. This is illustrated by the popularity of laptop / tablet (clipboard style laptops) and PDA computing, to the rapidly increasing capabilities of other mobile devices such as mobile phones (and more specifically smart phones), mp3 players and even clothing (incorporating many of the previous) and additionally, the increasing availability of wireless communication for all of these devices. Educators and technologists alike are interested in exploring the ways in which these devices, and more generally any devices (that is small, autonomous and unobtrusive enough to accompany us in every moment in our every day life) that may be used to enhance learning and provide an additional means of interacting with one another. This area of study is being referred to as mobile learning (m-learning), e-learning on the move (Sung, M et al 2005).

M-learning is still very much in its very early days of development. It is the point at which mobile computing and e-learning intersect. Considering that 50% of people do not sit at a desk, but are in-fact standing, walking or moving around a work place, m-learning technologies can potentially provide important opportunities for learning and collaborative interaction. Its obvious advantages are supported by evidence of m-learning beginning to take hold (Yuen, S., Wang, S. 2004):

- The average employee had less than three days of training in 2004.
- More than 525 million web-enabled phones will be shipped by the end of 2004.
- Worldwide mobile commerce market will reach £150 billion by 2004.
- There will be more than 1 billion wireless internet subscribers worldwide by 2005.
- Multi-purpose handheld devices (PDAs and telephones) will out sell laptop/desktop computers combined by end of 2005.
- Most major companies will either switch to or adopt wireless networks by 2008 (Ellis, 2003).

Investigating the cognitive and pedagogical aspects of m-learning is an important topic and to date, as with many e-learning developments, learner motivational factors findings have been reported even though these could also be considered a temporary side effect (Trifonova, 2003).

Research on course design and development for mobile learning (Sariola, Sampson, & Vuorinen, 2001) devices shows that the most important design aspect is the size, in terms of length and correspondingly data size, of the learning object being delivered. M-learning is most applicable to the need of short refresher courses or discrete pieces of knowledge needed on the spot rather than full learning programs (Ellis 2003) and can change some learners own behaviors by empowering the learner to a greater level mobility (Son, C., Lee, Y., Park, S. 2004).

As with many previous educational technologies, wide adoption into classrooms and company training strategies of m-learning will prove to be very slow. Presently many m-learning technologies are limited to content delivery onto mobile devices this inherently omits rich potential for more interactive learning models. One cause of limited adoption outlined by M. Sung et al (2005) is that practical issues such as usability, flexibility, and extensibility are often overshadowed by the need to quickly demonstrate the new features of the technology. Whereas more importantly the development of the foundation infrastructure necessary to make the technologies most effective, thus allowing easy deployment of highly interactive and personalised educational technologies.

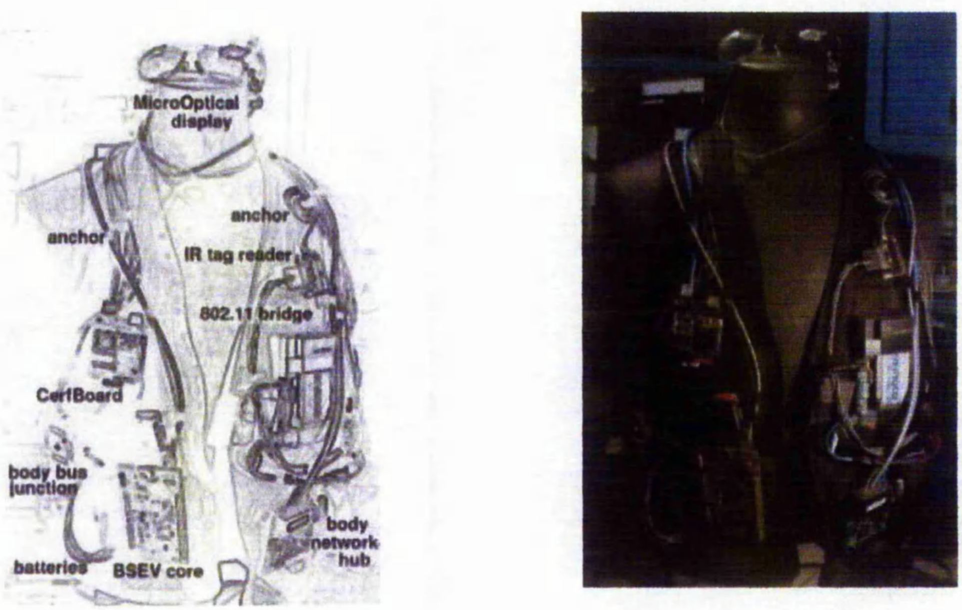


Figure 2.5 Diagram illustrates some of the more abstract work currently being undertaken within mobile computing that will influence the development of mobile learning hardware (from MIT http://www.media.mit.edu/wearables/mithril).

M. Sung et al add that several key components are necessary to create such a technology infrastructure for educational settings. First and foremost, a flexible and scaleable system architecture platform is required to be able to appropriately handle classroom settings, potentially involving up to hundreds of individual users. Second, the human factors side of the equation must be properly balanced, and the interface must be appropriately tailored to the application. M. Sung et al are currently working on MIThril at the MIT Media Lab (available at http://www.media.mit.edu/wearables/mithril) which is a research based on context aware wearable computing technology supporting rapid prototyping and rollout of large-scale community based applications such as support for military and emergency operations. Figure 2.5 illustrate a prototype of the MIThril research project.

2.4.4 Hybrid learning

Hybrid learning systems combine many of the above methodologies, learning systems and trends with one another creating a more effective and dynamic learning system. Combining a simulation and tutoring system can lessen the disadvantages of each of the systems, for example a hypertext and hypermedia system may be integrated into a tutoring system. In this case the hypertext or hypermedia presentation may sever as the main information source with additional detail being enhanced upon, illustrated and clarified by adding simulations other multimedia techniques. Tutoring and simulation systems support different learning styles and knowledge structures, with both of these systems imparting the same information but in different ways. The variation is inherent in the design of each of the systems and the teaching philosophies behind them.

'Blended learning' refers to hybrid learning methodology. The term blended learning is used in more corporate training environments than in educational institutions to describe a training solution that combines several different delivery methods, such as collaboration tools and software, Web-based hypertext or hypermedia courses and intelligent tutoring or tracking systems for example involving knowledge management practices. Blended learning also is used to describe learning that mixes various event-based activities, including face-to-face classrooms, live e-learning, and self-paced distance or directed learning. The four main models that blended learning focuses on are Skill-driven models, Behavior-driven models, Attitude-driven models and Competency-driven models.

2.4.5 Standards

E-learning Standards

Standards bring order to the world generally and even more so are paramount to collaborative development of technology. E-learning standards are bringing benefits to the field by allowing courseware builders to construct components completely independently of management systems under which they are intended to run. This approach extends the courseware's life expectancy by ensuring compatibility with updated systems or completely new learning management systems. E-learning standards ensure interoperability as well as reusability, durability and accessibility. HTML is a good example of such a standard. Over the years HTML has developed to HTML 1,2,3 & 4 and now XHTML (extendable). The World Wide Web Consortium (W3C http://www.w3.org/) is the international body that defined these specifications and others such as the "Web Accessibility Initiative," regarded by some as being central to developing a holistic approach for e-learning accessibility (Kelly, B., Phipps, L & Swift, E. 2004).

Standards specific to the e-learning have been slow to evolve. The aviation industry was one of the first to formulate such standards. The Aviation Industry CBT Committee (AICC http://www.aicc.org/pages/aicc3.htm) defined guidelines for the interoperability between CBT courses and other training technologies such as computer mediated/managed instruction (CMI), although not widely adopted outside government and commercial aviation industries the underlying work on these standards makes up the ground work of today's standards.

The IMS (Instructional Management Systems) Global Learning Consortium "develops and promotes the adoption of open technical specifications for interoperable learning technology" (IMS http://www.imsproject.org/metadata/index.html). It is the standards related organisation that receives by far the most frequent mention in journal papers, articles and special issues in the educational technology community. Its specifications deal with describing learning content, discovery and reuse content and assure that content is fully interoperable. XML a specification of the W3C is the international language of all IMS specifications which in itself represents a level of built in interoperability and durability, however, the specification go much further. The IMS Meta-data Specification defines a method for describing learning content by the title, author, location (URL), cost and payment structure, prerequisites, instructional design, and much more.

Once a piece of learning material is 'tagged' with meta-data finding, organising and reusing this learning material by others is much simpler.

The IEEE LTSC (Institute of Electrical and Electronics Engineers, Inc., Learning Technology Standards Committee) is a much larger association. Within the IEEE, the LTSC is chartered by the IEEE Computer Society Standards Activity Board to "develop accredited technical standards, recommended practices, and guides for learning technology". The LTSC also "coordinates formally and informally with other organisations that produce specifications and standards for similar purposes" (LTSC http://ltsc.ieee.org/). These other organisations include the IMS Consortium and the e-learning standards development body in the ISO/IEC (International Standards Organisation/International Electrotechnical Commission). The IMS, and ARIADNE (Alliance of Remote Instructional Authoring and Distribution Networks for Europe) began the joint development of the Learning Object Metadata (LOM). The development of the LOM was subsequently handed over to the IEEE LTSC, where, after multiple drafts and revisions, it was developed into an official IEEE standard.

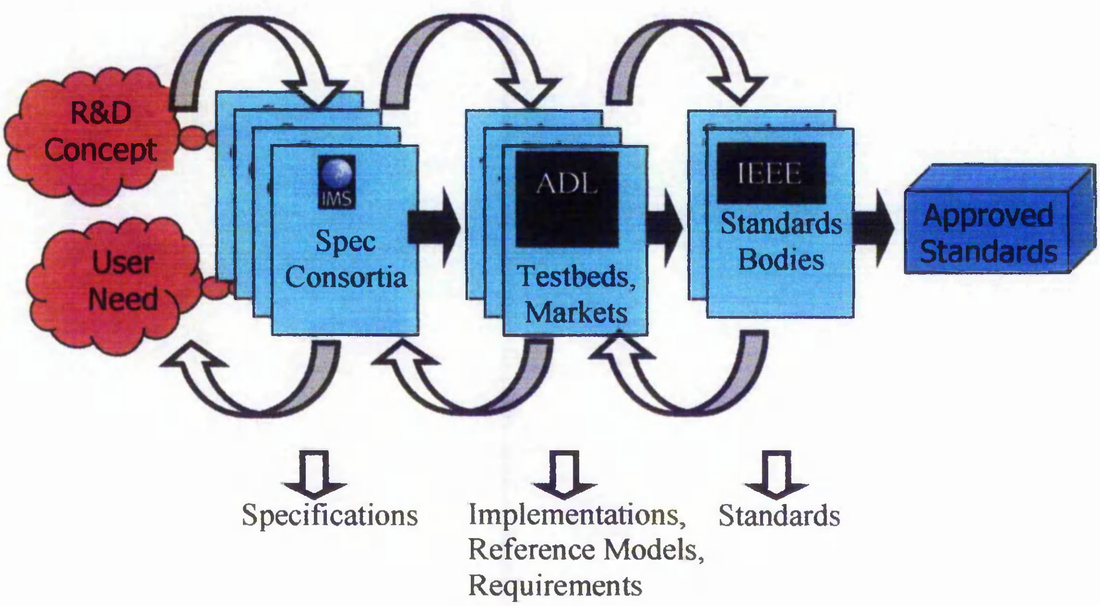


Figure 2.6 Diagram illustrating the processes, steps required and current bodies involved in these processes for the generation of a) specifications b) implementations, reference models and requirements and finally c) approved e-learning standards (from IMS Global Consortium).

In 1996, a need to fuse the numerous specifications by the AICC, W3C, IMS and IEEE LTSC into an all encompassing standard for the next generation of online e-learning was addressed. The work began in the formation of the Advanced Distributed Learning initiative ([]). The ADL built on the previous work of all of the specifications and brought them all together to offer a specification defining, packaging, and managing learning objects. This specification is known as the SCORM model (Sharable Courseware Object Reference Model). The standardisation process is illustrated in figure 2.6.

The sharable content object (SCO), the ADL name for a learning object, is the building block of a topic, a lesson, or a course. SCORM defines an API for a learning management system (LMS) to manage and communicate with SCOs and for SCOs to communicate with the LMS. SCORM is a model for designing an interoperable, durable learning system. It does not specify a programming language, authoring tool, or operating system; however, most implementers use XML, Java, JavaScript, and HTML. Furthermore, SCORM does not (currently) address instructional design issues, nor does it prescribe specific functionality for LMS's.

IMS Learning Design (IMS LD) is a specification related to instructional design. This working group subsequently undertook the task of simplifying the "Educational Modeling Language" or system developed by Dr. Rob Koper, and adapting it to existing IMS specifications, including the IMS version of LOM. IMS Learning Design was released as a "Version 1.0" IMS specification in February 2003, and its subsequent uptake and implementation has involved a wide variety of international initiatives or groups, as well as some systems vendors. These include the Valkenberg group (http://www.valkenburggroup.org/valkenburggroup-org.htm), the European-based UNFOLD (https://www.unfold-project.net/) community, as well as Blackboard (www.blackboard.com), elive Learning Design (http://www.elive-ld.com/content/index_ger.html), and Learning Activity Management System International (LAMS, http://www.lamsinternational.com/).

Other groups include the Centre for educational technology interoperability standards (CETIS http://www.cetis.ac.uk/). "CETIS represents UK higher-education and further-education institutions on international learning technology standards initiatives", and The Customised Learning Experience Online Lab (CLEO http://www.cleolab.org/) which is a one-year research collaboration between corporations interested in e-learning, academic researchers and the U.S. Advanced Distributed Learning Initiative (ADL). Founded by Cisco Systems, Click2Learn, IBM Mindspan Solutions, Microsoft and NETg, the CLEO Lab goal is to conduct focused, applied research on technical and pedagogical issues related to the ADL SCORM, an important compilation of e-learning interoperability specifications.

Multimedia standards

The richness in multimedia content and increasing heterogeneity of networks and user devices is making interoperable multimedia communications difficult. Standards are needed to enable multimedia content access under a wide range of delivery conditions and usage environments. Some more recent standards that are directly applicable to e-learning include:

Flash Open File Format, developed by Macromedia, is a multimedia Web tool that is used to create vector based graphics and animations. Flash Open File Format is now considered a cross platform file format and is effective at delivering scaleable graphics, animations, interesting interactions and Web applications at minimal bit rates.

MPEG4 evolved for multimedia applications mainly high quality internet video where a whole DVD's worth of video can be encoded onto a single CD was approved in October 1998.

MPEG-7 is orientated towards content representation for search, filtering, management and processing purposes. More specifically it is seeking to provide a multimedia content description interface providing support to a broad range of applications, for example, multimedia digital libraries, broadcast media selection, multimedia editing, home entertainment devices, etc. MPEG-7 provides the means for making the Web as searchable for multimedia content as it is searchable for text today. This would apply especially to large content archives, which are being made accessible to the public, as well as to multimedia catalogues enabling people to identify content for purchase. The information used for content retrieval may also be used by intelligent Web agents, for the selection and filtering of broadcasted "push" material or for personalised advertising. Additionally, MPEG-7 descriptions will allow fast and cost-effective usage of the underlying data, by enabling semi-automatic multimedia presentation and editing

The MPEG-21 standard promises to standardise descriptors for multimedia content access and allowing standards-compatible technologies to be used for adapting multimedia content. MPEG-21 seeks to achieve interoperable multimedia communication across networks and devices. MPEG-21 addresses device and format coding independence by standardising descriptors of usage environment and bit-stream syntax. Streaming of audio-video resources and adapting of images according to terminal capabilities, MPEG-21 is attempting to solve the challenging and important problem of universal multimedia access.

SGML stands for Standard Generalised Markup Language; another formal way of naming it is as the standard ISO 8879:1986 of which HTML is a by product. However, SGML was not intended for multimedia representation, nevertheless the fact that it is a metalanguage, (a language for formally describing a language, in this case a markup language) have made it become generally used for multimedia representation. The key concept that allows this is the DTD or Document Type Definition. A DTD allows defining a class of documents, indicating the type of elements one can find in a document, giving them a specific name. These elements can have attributes (also named). With the DTD a rich semantic structure amongst the elements can be established.

Dublin Core Metadata initiative (DCMI http://dublincore.org/) is an initiative to make it easier to find resources using the internet through developing and maintaining metadata standards, defining frameworks for the interoperation of metadata sets and facilitating the development of disciplinary specific metadata sets. Dublin Core Metadata a proposed standard for metadata defines a minimal, but sufficient, core set of attributes, or elements, which can be used to provide a basic description of a resource. The current DC metadata set comprises 15 elements, grouped into three categories:

- The Content category includes: Title, Subject (simple keywords or terms), (textual) Description, Source, Language, Relation (second resource, and its relationship), (temporal or spatial) Coverage

- The Intellectual property category is composed of: Creator, Publisher, Contributor, Rights

- The Instantiation: Date, Type, Format, Identifier.

RDF standing for Resource Definition Framework and is a language for expressing metadata that should provide for the exchange of machine-understandable information about Web resources and provide the facilities for the automatic processing of these resources. It is based on XML and is a work in progress of the W3C. In RDF each vocabulary is uniquely identified for a target metadata application through the definition of schemas, composed of the elements, the values these elements can have and their semantics.

Dublin Core Metadata and Resource Definition Framework standards are building block for the creation of a semantic Web and more specifically to e-learning an educational semantic Web. The semantic Web is the emerging landscape of new Web technologies aiming at Web-based information and service that are understandable, easily searchable and reusable by both humans and machines. Automatic discovery, invocation and composition of educational Web services can free the learner from many time consuming activates that often disrupt the learning process. An interesting area of research is looking at how the semantic web and adaptive hypermedia can merge and interact, benefiting each other (Sampson, D. G. et al 2004).

2.4.6 Summary

Tutoring systems and drill type learning programs generally lack the sound instructional messages discussed earlier in the chapter. These types of learning systems are argued to have a place in electronic learning in supporting and providing strong regulation for learners with low knowledge of the subject matter. This type of system methodology is one of the models employed in the experimental research. Hypermedia systems are generally non-linear, freely exploratory learning systems that support a constructivist approach in allowing multiple pathways for discovery in a more non prescriptive manner. The learner constructs their own knowledge and is allowed a greater degree of freedom to regulate their learning. At the same time hypermedia systems and constructivist approaches suffer from providing too many options with a danger of all material not being discovered, especially for the low knowledge learners. This type of learning system is also employed in the experimental research investigated here, and a discussion on regulation and its consequences is presented. This combination of learning systems is an example of a hybrid learning system that is typically designed to employ many non-technological, technological and pedagogical models benefiting from several approaches.

In addition to the two directly implemented technological models, the experimental and theoretical research seeks to investigate the appropriateness of this learning material being implemented for mobile learning technologies and more specifically, and importantly, the suitability of incorporating this type of learning material into a collaborative, socially supported learning systems, such as a virtual learning environment and/or a managed learning environment.

3.0 Design specification

3.1 Overview of the design

The research project initially set out to design and develop a series of interactive multimedia learning objects that may be utilised as stand alone learning/teaching aids, or be compiled as a collection of material within an electronic learning package. Two main types of learning packages were devised and examined. These comprised of one traditional learning package and one electronic learning package.

The learning materials primary function will be to focus on providing enriched learning support to the intended learners. The target learners are undergraduate students in their late teens and early adult life with developed computational and recently practiced learning skills (A Levels or similar type learning being a requirement of the University entry system). The electronic learning material courseware is produced as a hybrid learning system allowing learners to access learning material as a means of pre-learning, before an actual lecture based course itself, or post learning revision, to provide reinforcement as a way of reinforcing the knowledge delivered during the lecture based course.

The content rich multimedia electronic learning material may be presented in a high and low quality version on an optical medium such as CD-Rom or DVD-Rom; the choice of which rests with the institution or individual personal computer compatibility requirements.

The learning material was designed and developed by applying the nine multimedia design principles of Mayer (2001) reviewed in chapter 2.3.3, and combining these with instructional design theories, discussed later in this chapter, that are predominately based on a behaviouralistic approach to learning. The evaluation of the learning material developed was based on Kirkpatrick's formative evaluation model of training (Kirkpatrick, 1996).

Undergraduate students and academics within the Nottingham Trent University's School of Computing and Technology and School of Art and Design formed the demographic test base of the learning material.

Pre and post-test evaluations were devised to collect data regarding the learner's knowledge prior to viewing the learning material and after viewing the learning material. Additionally, learners experiencing the electronic learning material were asked to fill out feedback questionnaires regarding their attitude towards the material and their perceived learning experience. The results obtained from the pre/post tests, questionnaires, observations are analysed and compared to results from the traditional learning material group.

3.2 Subject matter

The subject matter chosen for the practical project is based on a visual perception module delivered for many years to undergraduate students on the Electronic Engineering degree course at Nottingham trent University, and more recently to students of the Multimedia and Audio Visual degree programs. More specifically, the learning material has been designed to be used as part of the visual perception module and acts as a first contact with the subject matter for the students at during their degree courses. This was specifically arranged so that the outcomes of the learning could be easily examined. The learning materials title is 'A general introduction to the human visual system'.

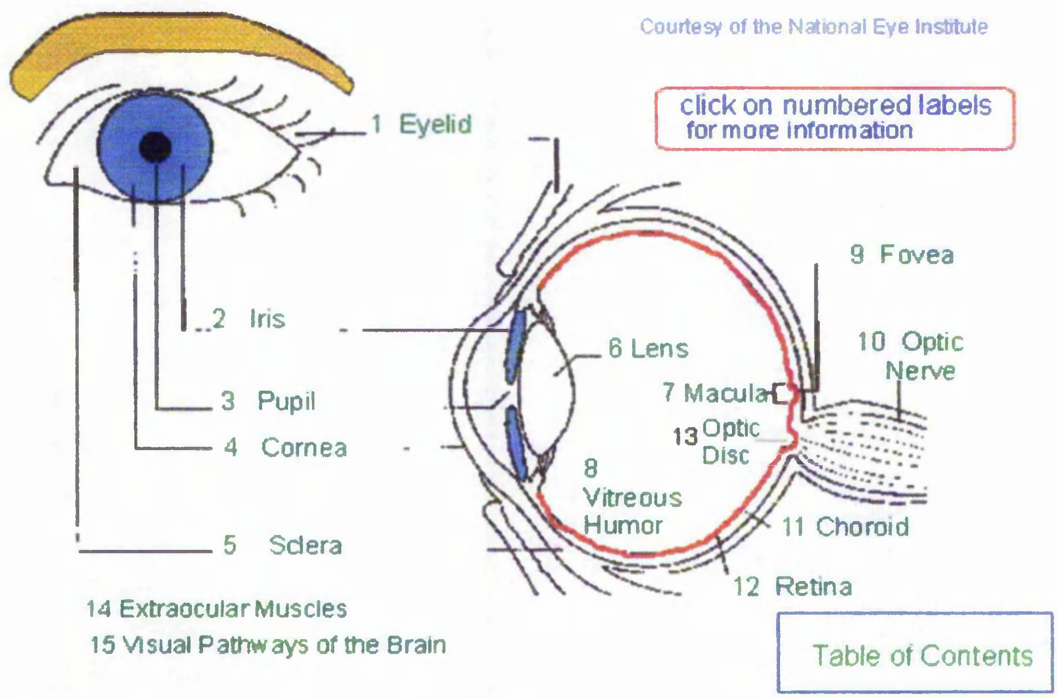


Figure 3.1 illustrates typical, traditionally used learning material for the subject of visual perception. This particular material is in electronic form however, the linearity of the information follows a traditional text book style presentation.

This particular subject matter was chosen due to elements of the subject's makeup being abstract and serve the purposes of this investigation well, in that the physiological makeup and mechanisms of the human visual system are abstract and present numerous difficult to understand structures and processes that are fundamentally problematic to convey to learners. Traditionally, the subject has been taught by the use of static illustrations and text description. This type of learning has been disseminated to learners via lecture based teaching as well as hypermedia based tutorials. An example of such material is illustrated in figure 3.1, which is taken from the National Eye Institute http://www.nei.nih.gov/health/.

Additionally, the subject matter is one that is familiar to the author and the director of studies, Dr Wayne Cranton. Dr Cranton has experience in delivering the subject of visual perception to students at the Nottingham Trent University for numerous years. During the course of the project Dr Cranton acted as the subject expert and further technical assistance was provided by Dr Crantons wife Patti K. Cranton (http://www.austenoptometrists.co.uk/optometrists.htm) whom has a long working professional history in optometry and retinal photography.

The subject of visual perception and the human visual system is applicable to many fields of study in biological areas and optics, for example, application to numerous medical fields and various engineering based subjects such as displays, photography, film and video.

3.3 The design team

The development of electronic educational courseware typically necessitates a design team with the following roles:

- Instructional Designer
- Interface Designer
- Graphic Designer/Developer
- Audio/Video Specialist
- Web Developer/Programmer
- Project Manager
- Editor/Content Writer
- QA Specialist
- Usability Specialist
- Information Technology Liaison
- Subject Matter Expert
- Multimedia editor

There may be instances where one enthusiastic individual will take on all the above roles. However, this is highly unusual that one such person will possess all the relevant skills and knowledge required to successfully carry out all roles. The number of people required will usually depend on the nature of the material being produced and the organisation human resource framework.

As discussed above, for this projects, subject expertise was provided by the director of studies, and the author constructed the instructional design of the learning material which was implemented in accordance with instructional design models such as ADDIE (Fardouly 1998) and Mason (1998).

Project management and usability of the learning material was jointly discussed between the author and the Director of Studies. However, it was necessary for the author to act in a multipurpose role covering graphic design / development, audio/video production, information technology liasing and multimedia editing. The university's e-learning manager Mr. B. Rotherham was called upon to assist with the evaluation and assessment design ensuring that the assessment of learning, and the results collected were accurate and aligned with practitioners accepted good practice. The technical team in the School of Computing and Technology were called upon for support with problematic issues such as DVD authoring and computer system and network related issues. Additionally other advisors were also consulted on various aspects of the project, namely: Multimedia lecturer, Ms. Ally Mozier – Graphic design and multimedia consultant; Multimedia lecturer Dr. David Downes – Lingo programming; Audio video technician, Justin Davey – DVD authoring software and technical A/V support.

3.4 Instructional System Design (ISD) of courseware

There are more than 100 instructional design models, however most are based on the generic ADDIE model outlined below (Gagné, Wager, Golas, and Keller, 2005; Reiser and Dempsey, 2002):

Analysis --> Design --> Development --> Implementation --> Evaluation

This systematic approach to development has many advantages with regards the creation of technology-based learning. During the analysis stage a clear understanding of the "gaps" between the desired outcomes or behaviours, and the learners existing knowledge and skills are identified. The next step is the design phase that documents specific learning objectives, assessment instruments, exercises, and content. The actual creation of learning materials is completed in the development phase. During implementation, these materials are delivered or distributed to the student group. After delivery, the effectiveness of the training materials is evaluated.

The ADDIE model has been criticised in being too systematic, inflexible, linear and even too time consuming (Fardouly. 1998). To counteract these arguments a rapid prototype phase was introduced for this project to modify the basic ADDIE model. The rapid prototype phase is added after, or as an extension to the development phase. The evaluation typically looks at things such as how well the learners responded to the creative metaphors, how effective the learning activities are, and how well the program performs on the chosen technology platform. Based on the feedback, the design is revised and another prototype developed. This iterative process continues until there is agreement and confidence in the prototype.

Being introduced at an early stage in the ISD model, the rapid prototype phase allows for changes to be made and other prototypes developed. Consequently the phase allows for writers and instructional designers to proceed more efficiently since they know exactly what the program will look like and highlights most of the major technical problems early on allowing for quicker final authoring and programming.

This type of model is particular to a product driven project where the main aim is the production of a unique product. An example of a typical product model is shown in figure 3.2. Bergman and Moore (1990) developed the model for the sole purpose of producing interactive video and multimedia materials. These phases work in a loop and should be continually repeated to identify further improvements.

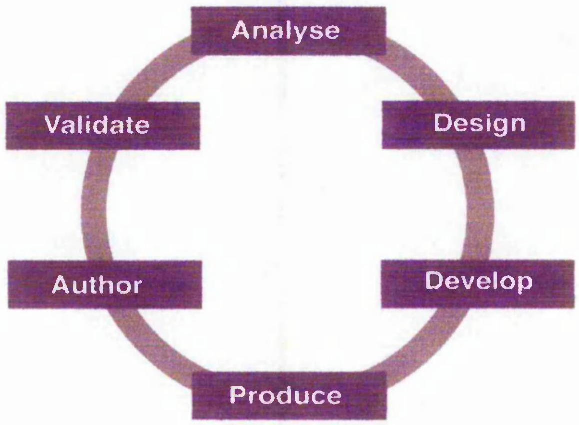


Figure 3.2 An instructional system design product model and the cyclic processes involved in the model.

3.5 Analysis phase

The analysis phase identifies the gap between actual behaviours against desired outcomes, and is useful in obtaining information about the learner, environment, and technology that are relevant to closing the gap.

This phase is the first and most crucial phase, with all subsequent work based on the outcomes of the analysis. Despite this, the analysis phase frequently is omitted from the instructional design process because it is perceived as unnecessary or too time-consuming.

Some of the tools that can be used to gather analysis information include:

- **Survey or questionnaire** is the most commonly used method in which specific questions are posed to a sample of the learner population.
- **Direct observation** has the designer personally observe learner tasks taking place.
- **Indirect observation** involves examining relevant performance data such as learner satisfaction surveys.
- **Interviews** put the instructional designer in touch with experts and/or a random sample of students through one-on-one interviews.
- **Focus groups** are similar to interviews only the designer poses questions to a group of experts or students. Data comes from direct answers, as well as from conversations among the focus group participants.

The first step in the analysis is to determine or clarify the instructional goals and desired outcomes. The immediate question that needs answering is 'what are we really trying to accomplish?'

For this project the instructional goals are as follows: To improve students understanding and maximise their retention of the workings of the human visual system, its mechanisms and its processes.

After defining and understanding the instructional goals, further analysis of all the subordinate tasks to achieve these goals is required. This step is critical in developing behavioural learning objectives and becomes the foundation for all of the content.

The following subordinate tasks may be identified for this project:

- Understand each element of the human eye.
- To know the workings of the eye.
- To build a deep understanding and lasting retention of the learning material

After understanding the desired goals and secondary tasks that will need to be satisfied, the learners themselves need to be profiled. Learner information impacts on all aspects of the design from appropriateness of metaphors to selection of content.

Topics explored in evaluating learners include:

- **Demographics.** What are the general characteristics of the target audience? Is there uniformity to gender, age, or educational background?
- **Psychographics.** What is the psychological makeup of the target audience? Do they want the information provided in a very direct manner or do they prefer a more time-consuming but engaging format?
- **Attitude.** What are the learners' attitudes towards the content or to training itself? What is the attitude toward the use of technology-based training?
- **Experience with technology-based training.** Will this be the first experience using the corporate Intranet for learning or are they already accustomed to navigating online material?
- **Motivation.** What are the learner's academic, work and career goals? How can the program assist them with the realisation of those goals?

- **Prior knowledge and experience.** What will the learners bring to the training in terms of knowledge and skills? To what extent are they currently working toward achieving the desired goals?

3.6 Design phase

The design phase examined the tasks or subordinate goals that were listed in the analysis and from these create a set of behavioural learning objectives. This was achieved by examining the following learning objectives which were derived from the analysis of the project. It was expected that after the learning experience is completed learners are able to:

- Understand the outer and inner structure of the human eye and be able to identify the elements that make up the eye.
- Explain the role each of these elements has and the mechanisms that govern them.
- Examine how the lens elements work together to produce an image.
- Understand the structure of the retina.
- Explain imaging on the retina and how this image is passed on to the brain.

Demographics

The target audience for this project includes secondary school students preparing for A' level in a relevant subject, undergraduate students on various degree programs as well as being applicable to postgraduate students on courses where they may never have been taught this specific subject matter as part of their undergraduate degrees. The age group of this audience may be defined as 16+ with no preference to gender and assumed minimum background education of secondary school GSCE standard biology, however this is not essential. The majority of students are expected to be within the 18 – 25 year old range.

Psychographics

The psychographics considerations of the target audience were not included in this stage of the research project design. Devising learner centred/customised learning is investigated and discussed as an influence on the results of the practical research. However, this is not a factor under investigation in this project. Hence, adaptation of the learning styles customised to the individual learner will not take place with this learning material.

Experience with technology-based training

As part of the practical research a questionnaire profiling the students' previous experience specifically with electronic based learning and more generally their level of competence with the use of information technology was evaluated. The questionnaire was devised as part of a pre-test.

Motivation

The learning material being produced acts as a learning aid to the students. A factor to consider is that failure of the students to complete the learning material is experienced in many electronic learning courses. This failure is mainly caused by the lack of motivation or the feeling of isolation experienced especially by online learners and primarily towards the end of the course. However, this factor is not expected be a significant factor for this particular learning material as it is comparably short, equivalent to a chapter in a text book. The students are expected to welcome a dynamic learning activity as opposed to repetitive traditional methods. Additionally as the majority of learners will be between 18 – 25 years old learning with the aid of information technology should be well received.

Prior knowledge and experience

As part of the pre-test to be conducted prior to exposure to the material, the students' knowledge of the subject area is evaluated. The pre-test results were used to compare results from the post-test and aid in drawing discussions and drawing conclusions.

Technology specification

As part of the final stage of analysis an investigation into the technology available to the student audience was conducted. The following factors were considered:

- The speed and processor type (e.g. Pentium II).
- The amount of memory or RAM available (e.g. 128 megabytes).
- The type of operating system (e.g. Windows 98/Me/NT/2K/XP).
- Optical drive compatibility? (e.g. DVD-Rom, CD-Rom)
- Whether or not there is audio capability.
- The screen resolution available (e.g. 800 x 600).
- The video standards available? (e.g. Windows AVI, MPEG, QuickTime).
- Whether or not there is an Intranet or Internet connection.
- Whether the connection is high bandwidth (Ethernet) or low bandwidth (dial-up modem).
- The browser and version that is available (e.g. MS Internet Explorer 5.0, Netscape 4).
- Browser plug-ins available (Shockwave, Flash, RealVideo).

The prototype module developed acted as an experimental module. It was designed to run on many configurations of Microsoft Windows and Macintosh compatible personal computers. The exact minimum specification of the computer systems for running the learning material was determined after testing of the rapid prototype had concluded.

The main technical requirement was to ensure that the learning material would playback on as many target personal computers without interruption and without dropping any frames of the animations ensuring synchronisation with the audio narration. Minimal load times of each of the sections was a secondary requirement and was allowed for by limiting the amount of content loaded into RAM at any given time.

During the prototype development and testing, compression of the images, text and sound was experimented with. Compression enabled a saving of approximately 50MB from a 90MB executable file a saving of 40MB. It was found that with the content having to be uncompressed load times dramatically increased on low specification systems, specifically those with poorer class CPU's or low on chip cache memory i.e. Intel Celeron and AMD Duron type processors. The saving of approximately 50MB was deemed as not significant enough to warrant the increase in load time, it was therefore decided that compression of this content would not be used as substantially greater saving could be made on compromises with the video content.

The video data, considerable in length, consisting of 9 minutes of continuous video playback accounted for the bulk of the data. The Cinepak video compression algorithm was chosen and a resolution of 640 x 480. The compression design choice ensured compatibility on a number of systems and balanced data rates with minimal compression artefacts while sustaining support for a low computational intensive system. The downside of this design choice was that to support 640 x 480 video the data rate of the learning material video resulted in 2000KB/s. The resolution could be reduced, however any significant reduction, i.e. 320 x 240 would result in the user struggling to view the material in its entirety. This is relatively high data rate and therefore requires a 16 x CD-Rom or a 2 x DVD-Rom and a personal computer capable of reading and processing data at this rate for continuous playback.

The learning material does not require installation since it is a self contained DVD-Rom and may be played back from the DVD itself. However, if stuttering or long load times are experienced then installation of the files is recommended. This is a simple process of copying the files into a directory on the users system. With the learning material amounting to just over 1000MB CD-Rom delivery requires the files to be installed on the users system.

The following computer specification are therefore recommended: Higher end (500MHz) Pentium II or equivalent CPU, 128MB ram, operating system supported Microsoft Windows 98/NT/2K/XP or Macintosh OS Classic and OSX, sound capabilities, 16 x CD-ROM or network connection to a machine with a 16 x CD-ROM drive, minimum screen resolution of 800 x 600, Quicktime video playback required.

Design of the traditional paper based Learning Material (TLM)

The text and graphics (appendix B) section of the distance-learning package was created using three references, The human eye: structure and function (Oyster 1999), The eye and seeing (Ward 1989), The human body, the eye (Elgin 1970). These were selected to give an accurate representation of literature available for traditional means of learning. Other sources of information included numerous Internet references such as (Kaiser http://www.yorku.ca/eye/thejoy.htm) and subject area experts such as optometrist Patti Cranton.

Text and graphical illustrations were taken from these references and edited using generically practised image manipulation and desktop publishing methods. The text and illustrations from 'The eye and seeing' were employed to a greater degree than any of the other two references this was due to 'The eye and seeing' being specifically purported to a novice knowledge level of the human visual system and was thus directly aligned to the purpose of the experiment.

The traditional paper based learning package is a self-contained learning reference that utilises large sections of text and detailed diagrammatical illustrations to describe and discuss the following topics:

- Structure of the human eye.
- Movement of the eye/s.
- The lens system and its mechanics.
- The retina and its structure
- Cells within the retina and their function.

Design of the Electronic Learning Material (ELM)

The electronic learning material (appendix C – DVD-ROM format) developed by this practical research project consists of video and narrative sequences detailing each section of the human visual system and depicts the physiological processes that occur. The video content was made up of 3D animated models that were designed to include visual cues (signals) consisting of labels and highlighted areas of the image. These types of cues have been seen to enhance comprehension and retention in animated learning material (Huk, T. Steinke, M. Floto, C 2003).

The electronic learning package comprises of a navigable, partially interactive multimedia rich presentation consisting of a number of learning objects. Developing the learning material as individual learning objects allowed for each of the topics to be broken down into small sized learning sections. This type of design allows for each of the sections to be created independently and also permits, if necessary, several versions of each learning object to be developed. The learning objects were comprised of the following elements of media:

- Simple paper based text and illustrations.
- Graphics, diagrams, images, two dimensional animated diagrams / images / graphics.
- Video media created through the use of three-dimensional computer generated imagery and also traditional video production techniques.

Once created, learning objects allow interactive multimedia learning content to be easily managed either by compiling and authoring the learning objects as part of a stand alone learning aid or as part of a more advanced external learning management system.

The informational content contained in the package was similar to that presented in the paper based version. The storyboard and running order of the package was derived from the paper based learning material, hence ensuring consistency between the comparative packages. Figure 3.3 illustrates the structure of the electronic learning package and featured in a handout given to each of the participants of the electronic learning material experiments.

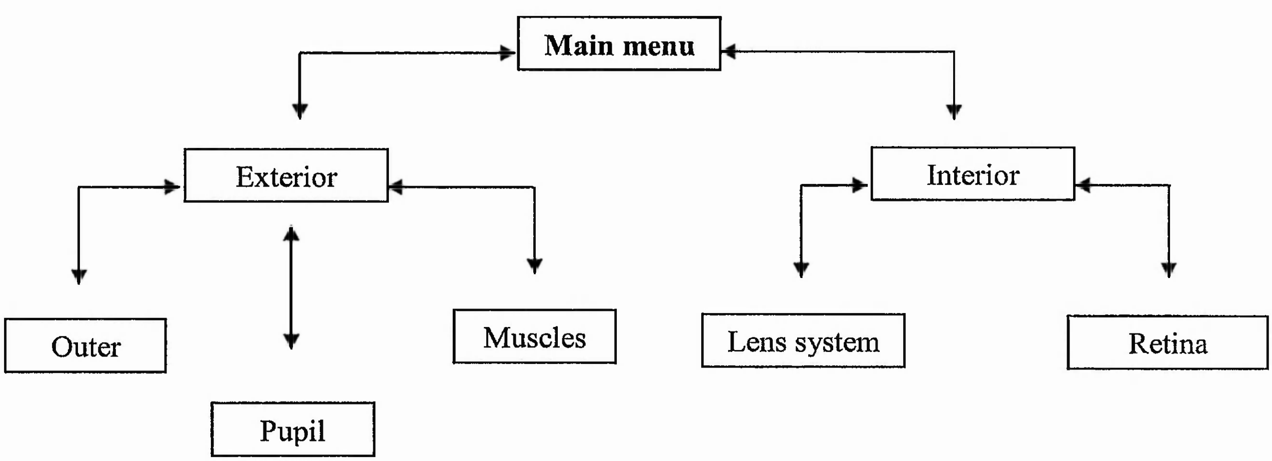


Figure 3.3 A flow diagram representing the structure of the electronic learning material and was presented to the participants to aid in navigating around the package.

The informative material was presented in various formats, these include:

- Static diagrammatical illustration; similar, and in some cases identical to those found paper based version.

- Simple animated two dimensional diagrams with minimal use of text cues (signals) aiding in the communication of the information.

- Complex, photo realistic three-dimensional animated models presented in a video format with minimal use of text cues.

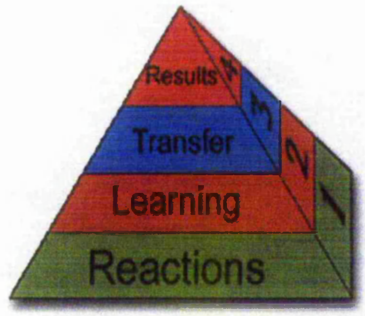
- Synchronised audio commentary describing and discussing material being presented.

Throughout the design phase attention to accessibility issues for learners with special needs was addressed. This was achieved by making design choices in line with generally accepted accessibility design code and accepted good practice. For example, contrasting colours were chosen at all times to optimise viewing of the material, text was as bold as aesthetically possible and easily readable fonts were be chosen. Flickering, blinking and moving text was avoided. A minimalistic approach to the design of the material ensured against cluttering and over complicating the user interface and the presented material.

3.7 Evaluation design

The evaluation of the learning material was designed to be based on the Kirkpatrick model of evaluation that follows a goal-based evaluation approach and at the time of design was an industry standard evaluation model used by instructional designers throughout commercial training (Winfrey 1999; Phillips 1997; Dixon 1996). It is based on four simple questions that translate into four levels of evaluation.

- Level One: Reaction
- Level Two: Learning
- Level Three: Transfer
- Level Four: Results



Level One: Students' Reaction

In this first level or step, students are asked to evaluate the training after completing the program. These are sometimes called smile sheets or happy sheets because in their simplest form they measure how well students liked the training. However, this type of evaluation can reveal valuable data if the questions asked are more complex, for example:

- The relevance of the objectives.
- The ability of the course to maintain interest.
- The amount and appropriateness of interactive exercises.
- The ease of navigation.
- The perceived value of the learning.

Level Two: Learning Results

Level two in the Kirkpatrick model measures learning results; Did the students actually learn the knowledge, skills, and attitudes the program was supposed to teach? To show achievement, the students complete a pre-test and post-test, making sure that test items or questions are truly written to the learning objectives. By summarising the scores of all students, it is possible to accurately see the impact that was achieved by the training intervention.

Level Three: Transfer

Students typically score well on post-tests, but the real question is whether or not skills and any of this new knowledge are retained. Level three evaluations attempts to answer whether or not students' behaviors actually change as a result of new learning.

Ideally, this measurement is conducted some time after the learning program. By allowing some time to pass, learners have the opportunity to implement new skills and retention rates can be checked. Observation and feedback surveys are used. Surveys can be completed by the learner and the learner's supervisor.

Level Four: Results

The fourth level in this model is to evaluate the resultant impact of the learning program. The only scientific way to isolate training as a variable would be to isolate a representative control group within the larger student population, and then rollout the training program, complete the evaluation, and compare against a non-trained group.

For this practical research the following forms of evaluation were designed that were derived from the Kirkpatrick evaluation model:

- A pre test (appendix D)
- A post test (appendix E)
- A questionnaire and feedback form (appendix F)

Pre-test evaluation (Appendix D)

The pre-test was designed such that a rapid evaluation of the participants' prior knowledge of the human visual system could be performed. The maximum score allocated to the pre-test was 36 marks. Employed on the first page of the pre-test is a diagrammatical illustration of the physiology of the human eye. The diagram features 12 unfilled spaces. These diagrams allowed the participant to demonstrate their initial level of knowledge of the physiological make up of the human eye by means of labelling each of the parts. Each of the parts was allocated 2 marks for correct identification, allowing a maximum score of 24 marks.

Additionally included in the pre-test to the previously mentioned diagram, were two short questions to evaluate deeper understanding of the basic mechanics and processes of the human visual system, these questions also required additional knowledge of the physiological make up of the human eye. These two questions were allocated 12 marks in total.

Post-test evaluation (Appendix E)

The maximum score allocated to the post-test was 56 marks. The questions ranged in difficulty and purpose. The evaluation opened with a similar diagrammatical labelling question as seen in the pre-test. In this instance the diagram required significantly less labelling and therefore had less significance weighting towards the overall evaluation, only 12 out of a possible 56 marks. Four of questions were written to focus on recall alone and accounted for 20 marks, whereas the other 24 marks were based on assessing the understanding of the various processes.

The post-test thus required longer for the participants to complete and in some circumstances the time available for participants to complete the test was limited. The post-test was designed to evaluate the participants' knowledge once the learning process had taken place. This was similar to the pre-test in format, however, more comprehensive in length and complexity. Specifically, the post-test emphasis was placed on evaluating the participants' level of understanding and retention of the various mechanical and physiological processes and concentrated less on identifying the numerous parts of the visual system.

Questionnaire and feedback form (appendix F)

In addition to the two test papers, participants of the experiments were asked to fill in a questionnaire and a feedback form regarding their experience of using the learning package. The questionnaire enquired into the following:

- Participants' previous experiences of using ELM's,

- The number of packages used.

- Where they had come into contact with the ELM's
- The subject matter covered.
- Their overall attitude towards using the experimental ELM.
- Their experience using the experimental ELM.
- How they thought the ELM may be improved.

The feedback form served as a means of further understanding the learners taking part in the experiments and enquired into the attitude of the learner towards the learning experience. The feedback form was made anonymous in an attempt to encourage the learners to express their true attitudes without bias. Ideas for ways that the learning experience could be improved were also asked for. This feedback was used to aid the modification of the material for the 2nd phase of experimentations.

In summary, the traditional learning material follows commonly found instructional design methods found with textual and diagrammatic learning material. The electronic learning material design follows good practice multimedia design for learning as outlined by Mayer (2001), Clark & Mayer (2003) and incorporates the most commonly used instructional system design methodology ADDIE. The design of the evaluation follows the summative Kirkpatrick model. In an attempt to enhance the evaluation and examine learners attitudes, more commonly used attitude questionnaires, made up of a mixture of Likert and semantic / differential scales are employed.

4.0 Methodology

The following chapter documents the development methodologies, experimental methodologies and accounts for the steps taken in the two main phases of experimentation of the practical research project.

4.1 Development of learning material - Rapid prototype

Some developers consider a prototype to be nothing more than a few screen shots that show the look and feel of the program. However, for other members of the design team to provide truly valuable feedback, the prototype must include a cross section of the entire program. This cross section is sometimes called a vertical slice.

A vertical slice of the entire program typically includes the title screen, Main Menu, one complete lesson, and occasionally a portion of the post-test. For this project the rapid prototype included a mock up of the title screen, an interactive 2D/3D diagram identifying each element of the eye and a brief post-test exemplifying the range of questions to be included within the main testing phase. This rapid prototype was scheduled for completion within a two-week period.

Upon approval of the design document and the rapid prototype the next step in the ISD process was followed in the development of scripts and/or storyboards (appendix G). The script and storyboard contained the following information:

Project Information includes the name of the client, curriculum title, course title, date, draft or version number, and script page number.

Audio/narration was detailed in the script, writing out in full the actual dialogue spoken by the narrator.

Animated video was described in the script, giving both camera direction and notes on parts of the narrated script to be synchronized at that point.

Graphics were provided in the script as a verbal description of what should appear on screen, this included mockup screens taken from the rapid prototype.

On-screen text section of the script describes which words will appear on the screen. In this program where audio narration is the primary instructional media, the text is used to reinforce the audio. The onscreen text mainly consisted of text cues and brief bulleted phrases rather then whole sentences and paragraphs.

Navigation and interactivity described the action items of the program, what the student could do on this screen, and what would happen next.

Scripting and/or storyboarding of the material commenced after the evaluation of the rapid prototype had concluded.

4.1.1 TLM development

The traditional learning material was developed using a number of software programs for image editing and desktop publication. Namely, Adobe Photoshop was used to scan and edit the number of illustrations included within the TLM package. Specific attention was paid to ensuring that the image being present was as clear and as close as identically possible to the original text book illustration.

Adobe Illustrator was used for desktop publishing purposes. The use of this program enabled the specific positioning of the text and illustrations to simulate the printed media from which it was taken. The text was initially transcribed from the printed media using a word processing program.

A finalised copy of the learning material was presented to the design team for proof reading before being reproduced.

4.1.2 ELM development

The learning objects were produced using various multimedia production methods. This included acquiring all asset material used within the project, designing all graphical material, building of all 3D computer models, recording and editing of all video and audio and scripting/writing all text based material. These tasks were mainly fulfilled using a variety of multimedia computer authoring software.

All the video and audio content followed identical production and authoring processes where particular attention was paid to ensuring that the content was consistent in emphasis, i.e. volume levels of audio, lighting of 3D models, colour and contrast settings and pace of information being delivered. The following production process occurred as depicted in Figure 4.1:

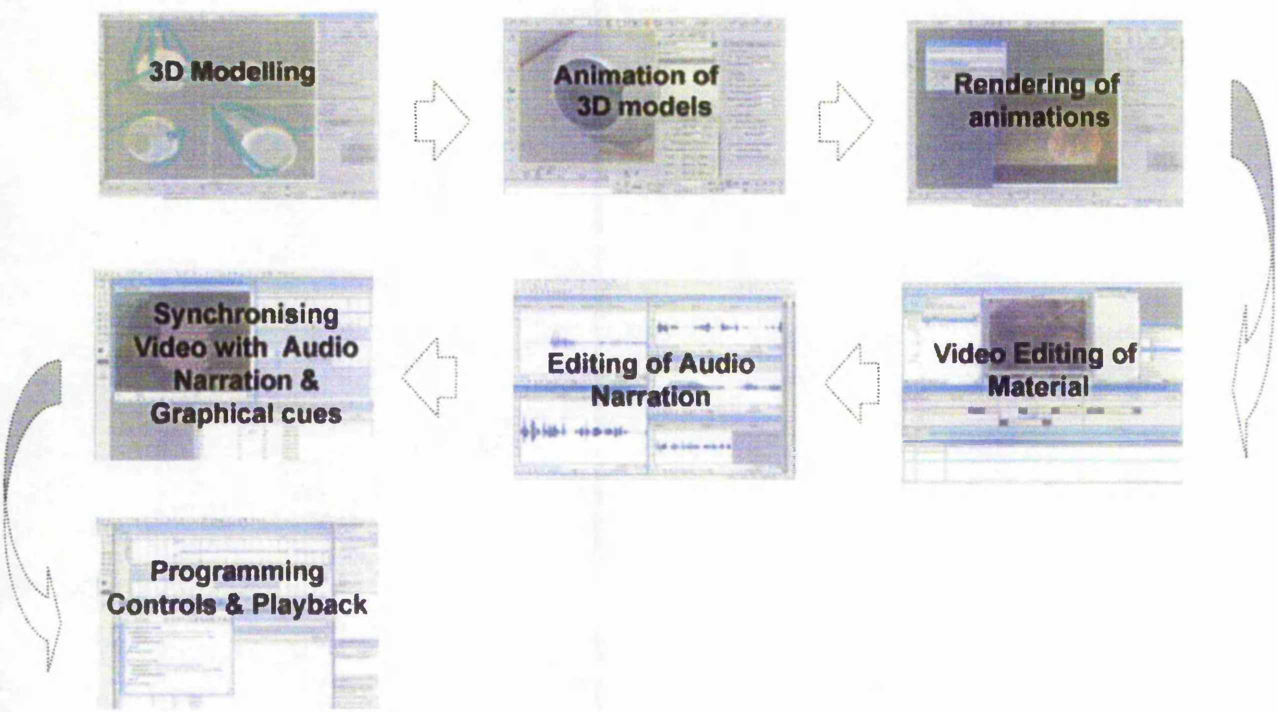


Figure 4.1 The various stages and media production processes involved in the creation of the electronic learning material.

The following software programmes were used in the production of the ELM package:

- Three dimensional modelling and animation programme Discreet's 3D Studio Max (www.discreet.com) used for 3D modelling, animation of 3D models and rending of animations to a Quicktime video format.

- Adobe Premier (www.adobe.com) and Apples Final cut pro used for video editing and video format adjustment purposes.

- Sony's Sound Forge (www.sony.com) used for audio editing and mastering purposes.

- Macromedia's Director (Macromedia www.macromedia.com) multimedia authoring programme used for synchronising video with audio narration and graphical cues. Director also used for programming controls, package playback, compiling and publishing.

During authoring of the package testing was carried out throughout by the author. Upon completion of the package the design team assisted in carrying out debugging of the package by using the learning material and searching for anomalies.

4.2 Experimental methodology

The experimental research was carried out over two phases with a gap of some three months between the tests. This enabled an additional test base of 1st year undergraduate students of similar background and demographic composition to be used in the experiments. Further, this time gap presented an opportunity for the author and other members of the design team to review the experimental process and the learning material and perform enhancements.

For both phases of experimentation learners were grouped in their scheduled classes and divided randomly to form two test groups. One group experienced the electronic learning material whilst the other was used as control being given traditional text and graphics. Each experimental phase thus consisted of two main groups of learner experiencing different learning packages:

1. A traditional distance-learning package consisting of paper based text and graphics, delivered in the form of a bond A4 paper handout.

2. An experimental electronic learning package comprising of a navigable, (partially interactive) multimedia rich presentation delivered via a PC of specification outlined in the previous chapter.

For each of the groups of learners above, the experiment comprised of three parts that were conducted for a maximum of one hour. During this hour each participant was asked to carry out the following tasks:

a) Complete a pre-test / evaluation. This was performed to determine the participants' prior knowledge of the chosen subject matter. This process continued for five minutes; some participants did take longer however a maximum time limit of 15 minutes was enforced.
b) Learning from the supplied courseware. Each participant was asked to learn as much information as effectively possible by use of the specified material. It was recommended that 30 – 40 minutes were to be spent assimilating the information.

c) Complete a post-test / evaluation. This was performed to assess the participants' retention and their construction of knowledge with regards the subject matter.

The participants were not limited to a fixed time scale on each of the sections however, a limit of one hour was enforced on the entire experiment due to logistics.

The experiment was conducted on nine separate occasions, with participants averaging 17 per group. A total of 151 participants took part in the experiments. The paper based learning package was delivered to four of the six groups. The results of the pre-test and post-test were evaluated for each of the participants and compared. The difference in scores from the two tests provided a basis for measuring, calculating and discussing to what degree learning had taken place.

The pre-test presented an opportunity to collect additional data about the participant that would aid in profiling the participants and providing further information for analysis. Participants were asked to provide a self assessment of their initial (before using the learning material) knowledge of the human visual system and whether they had been previously exposed to learning material associated to the human visual system, i.e. biology GCSE, A1/A2 level.

Sensitive data regarding student's previous academic results was collected providing another variable for comparison and analysis. Each student granted permission for this data to be used. This data was collected from the university admissions department and comprised of the student's entry grade into the university based on the UCAS tariff point system.

Observations by the author were made throughout all of the learning experiences, emphasis was placed on observing behaviours that could have influencing factors to the learning during the experience, if applicable these factors were noted on the learners test sheet.

4.2.1 TLM Experiments

The package was delivered to participants of the experiment in a bound A4 paper handout format that was easy to handle and effective for the purpose of study. The original package was authored in full colour with a resolution of 360 dpi on a high quality inkjet printer. Learning from the TLM occurred in exam type conditions in almost silence, with only occasional extraneous sounds and movement affecting the participants' concentration. Participants were observed to be more alert during the afternoon sessions rather than the morning sessions. The afternoon sessions were run from 13:00 – 14:00, whereas the morning sessions were held from 09:00 – 10:00. Each participant was expected to work individually. However, in some instances spacing between each of the participants did enable collaboration. Collaboration between the participants was discouraged and verbal warnings were given to those who insisted, participants observed to be collaborating and or acting dishonestly were noted and their papers were omitted from the results.

During phase 1 of the experimentation the reproduction of the TLM package required for 100 copies to be made. The departmental photocopier was used to produce monochrome reproductions of the learning material on A4 bound paper. This decision was principally due to speed, ease of access to the printing facility and the ability to personally control the reproduction to an adequate quality.

Unaware of the fact prior to testing most of the monochrome reproduction suffered from anomalies and artefacts resulting from a varying quality outputted half way through the printing process from the departmental photocopier. This was unfortunately not detected until testing had commenced and at the time of experimentation it was not possible to rectify. On analysing the reproductions, the errors had negligible impact on the text reproduction; all text was readable if in places a little faint, however, approximately 20% of the diagrammatical information was affected by reproduction. However of this 20% only 25% (conservative analysis) of the affected material could be deemed significant to the learning objectives and instructional messaging of the experiment.

These issues were resolved to some degree during phase 2 of the experimentation where the universities reprographics department and full colour reproduction of the material was opted for. The reproduction did not suffer from running low on toner during the printing however, even though specifying to take extra care over contrast settings to ensure all diagrams and illustrations would be clear and viewable, some low contrast detail was lost. The lost detail was unexpected as no signs of this possible error were perceived in phase 1 of the reproduction. The reproductions were non amendable.

In all other aspects phase 2 of the TLM experimentation was identical to that of phase 1.

4.2.2 ELM Experiments

The mode of deliver of the electronic learning material necessitated a change of environment. A computer suite comprising of thirty machines was used. This was a recently installed suite that was comfortable and provided an effective environment for learning. Similar to the paper based material experiment participants were requested to work individually and were invigilated. However, participants were positioned in closer proximity to one another compared with the paper based material.

The electronic learning package suffered various technical problems. These problems were largely the cause of hardware failure. University computer systems are intensely utilised by a large number of different users and are consequently prone to painfully slow operation and failure if not routinely and accurately well maintained. These problems affected the learning taking place and commonly caused user frustration which lead to concentration levels and motivation of the learner being lowered. This was unfortunate and also frustrating to the author whom on several occasions had requested that maintenance of the systems be performed prior to experimentation. Apart from these system problems, phase 1 experimentation of the ELM package took place issue free.

With the two phases of experiments being separate by a three month period, considerable time was available for reviewing and enhancing the ELM from the first phase of experimentation. The following points were noted during the initial experimentation and addressed:

The overwhelming feedback, comment and limitation identified during use of the phase 1 ELM package was that there was no means of navigating within a section of the package itself. Navigation options were only available to navigate through the package at a section level and each section had to run through to the end until the user could swap to another section. This was annoying and meant that repeating or replaying a section was not possible. The lack of navigation also resulted in the pace of learning being regulated by the design of the package and did not allow the learner self regulation of the speed at which they learnt. Teacher and student regulation has been seen to impact on the learning effectiveness (Vermunt & Verloop 1999) and will be discussed in the 'Discussions' section of the next chapter.

To address this problem each section was further broken down into several chapters depending on the size of the section. A maximum of seven chapters was used in the two largest sections the 'retina' and 'muscles'. Any of the chapters could be navigated to at any time from within that section. To implement this interface, graphic development and time consuming lingo programming involving meticulous work was required. The material being presented was made up of video and graphic overlays that had been authored in a way to allow simulations, tests and other interactive features to be implemented into the learning package. This seemed prudent at the design stage as it was anticipated that some of these features could be implemented, time permitting. Due to this capability it was not possible to include video controls such as forwarding, pausing, rewinding of the video, hence chapters were used. This again caused some minor frustration and is discussed in greater detail in the 'Factors influencing results' section of the 'Results, analysis and discussion' chapter.

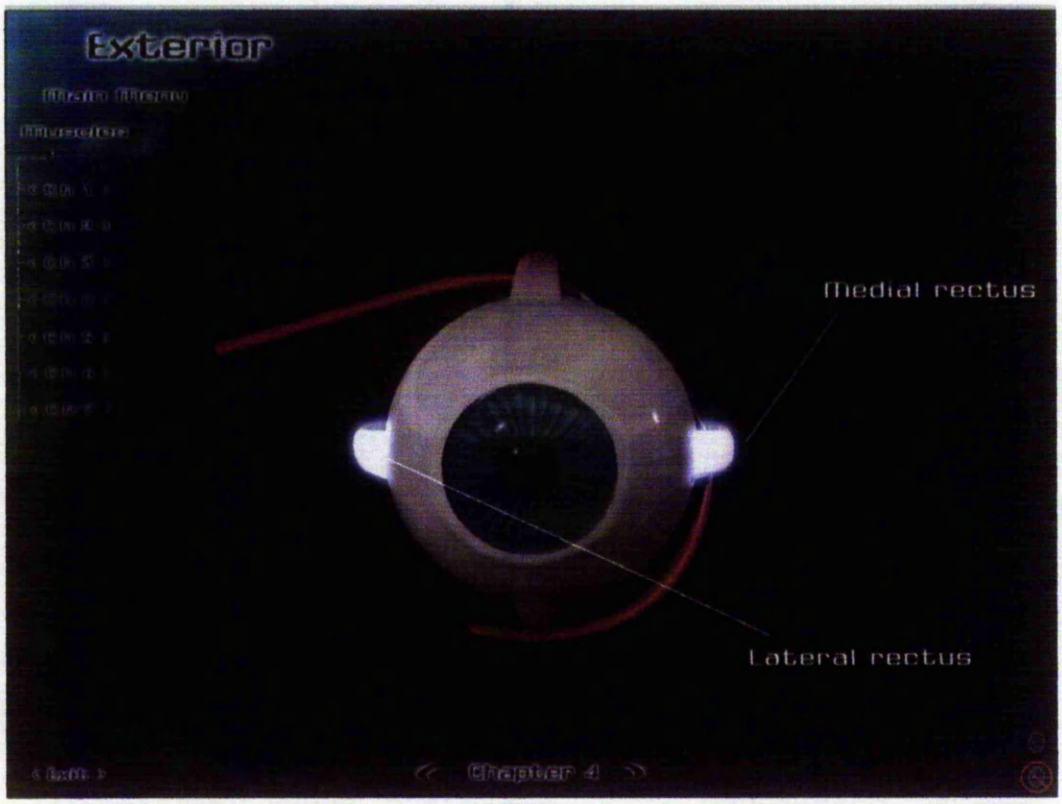


Figure 4.2 This 'screen shot' (still image capture of a computer screen) illustrates the 'Exterior' section of the ELM. The contrast differs to that presented in the experimentation on monitors.

Analysis of the feedback forms revealed that slight authoring errors were present in the phase 1 ELM package where two audio narrative phrases were cut mid sentence, these issues were identified and corrected during the redevelopment. Other feedback suggested that features beyond the scope of this experimentation be built into the design such as quizzes at the end of each section, additional text on screen for reading and additional music options.

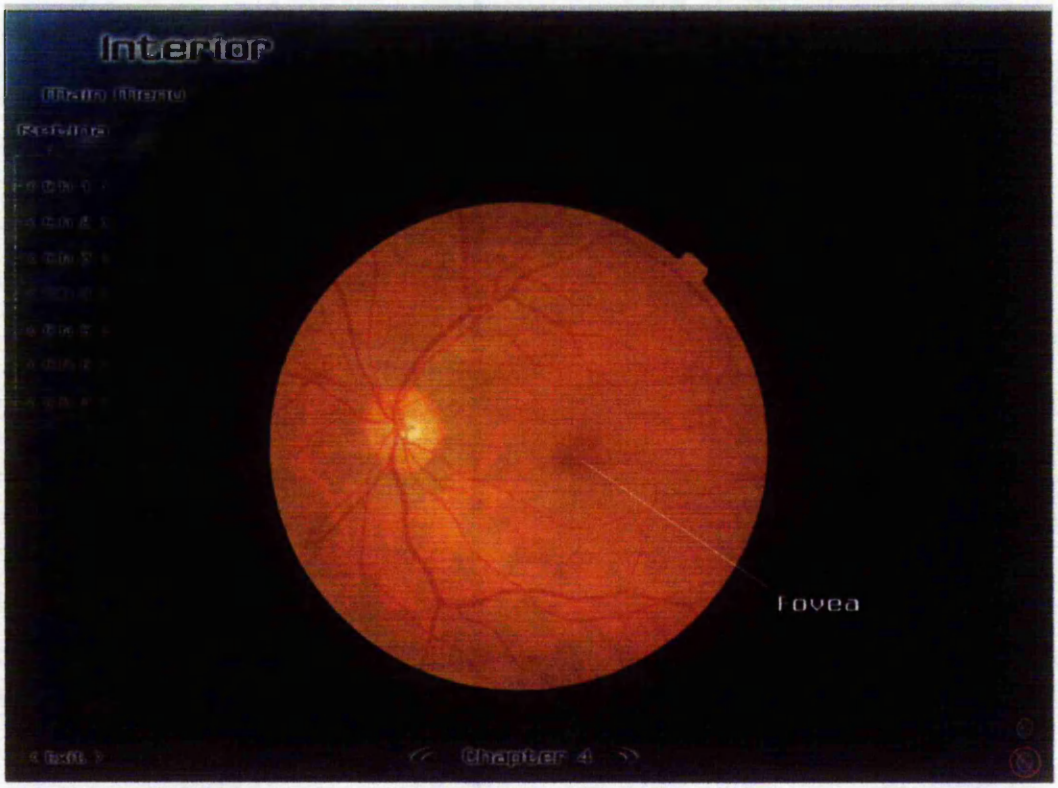


Figure 4.3 This 'screen shot' of the 'Interior' section of the electronic learning material and depicts a section that was omitted due to scripting errors. **N.B** The contrast differs to that which was presented to the participants on the computer displays.

During the 1st experiment of phase 2 script errors resulting from authoring oversights of the complicated navigational system were encountered. These led to two audio dialogues and diagrammatical images not being presented to the participants. Specifically, in the exterior section of the ELM under chapter 4, 'muscles_g.mp3' the sound bite (script may be found in appendix G) and diagrammatical illustrations such as figure 4.2 were skipped. These illustrated and verbally narrated the medial rectus and lateral rectus and the number of degrees that they rotate the eye.

The other scripting error occurred in the retina section under chapter 4 where 'retina_i.mp3' and figure 4.3 were skipped. Here the fovea of the retina was illustrated and explained. Although not a completely valid experiment these script errors were accounted for by removing the corresponding question from the post test and the scripting errors were rectified for the second ELM experiment.

5.0 Results, analysis and discussion

This chapter documents the experimental results obtained from this research and the analysis performed. It concludes by discussing issues arising from observations. Summaries of the results are presented in a number of forms for both phase one and phase two of the traditional learning material (TLM) and electronic learning material (ELM) experimentations. The full results may be found in appendix H, sorted into the two main phases of testing and further into experiment groups. Presented is data regarding number of students, pre and post test result, percentage differences between the pre and post test scores, UCAS tariff points of each student, age group, calculations tables and statistical analysis performed.

5.1 Results and analysis

A significant difference in the student intake numbers during the 2003/2004 academic year as opposed to the 2004/2005 years on the Multimedia courses at Nottingham Trent University lead to an undesirable difference in the number of test participants during the two phases of experimentation.

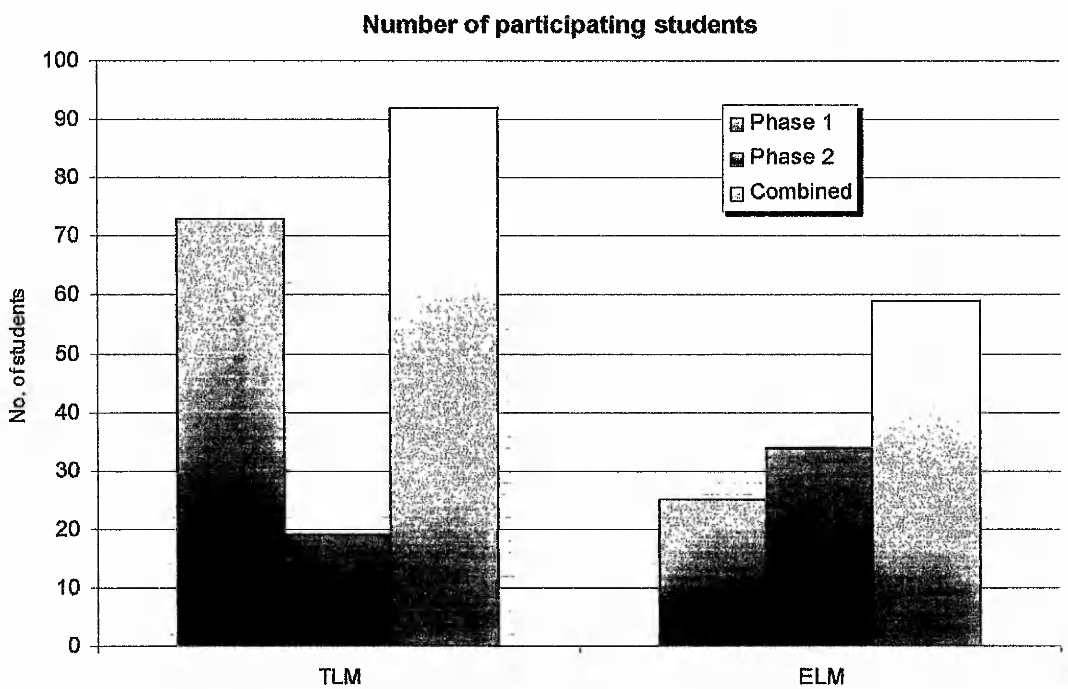


Figure 5.1 the number of participants taking part in the each phase and each set of the experiments.

From both year groups a total number of 151 participants took part in the experimentations. Of these 151 participants 76% were male and 99% were in the 28 – 25 year old age group. All participants were enrolled onto the Multimedia program at the Nottingham Trent University. Figure 5.1 displays the number of participants that engaged in the two phases of experimentation. The results reveal inconsistencies in the numbers of participants during testing. During phase one 73 participants took part in the traditional learning experiment, whereas only 25 took part in the electronic learning experiment. This discrepancy was due to problems in running the initial phase of the ELM during scheduled classes. Attempts to counter this bias were made in phase two where only 19 participants took part in the traditional learning experiment and 34 took part in the electronic learning experiment. Calculating the mean results was performed using participant numbers and their resultant scores. The combined results were aggregated and weighted according to the percentage of participants taking part.

Figure 5.2 and table 5.1 below summarise the difference in quality of student between the two sets of student groups that participated in the experiments. Phase one represents students from the 2003/2004 academic year group, whilst phase two represents students from the 2004/2005 academic year group.

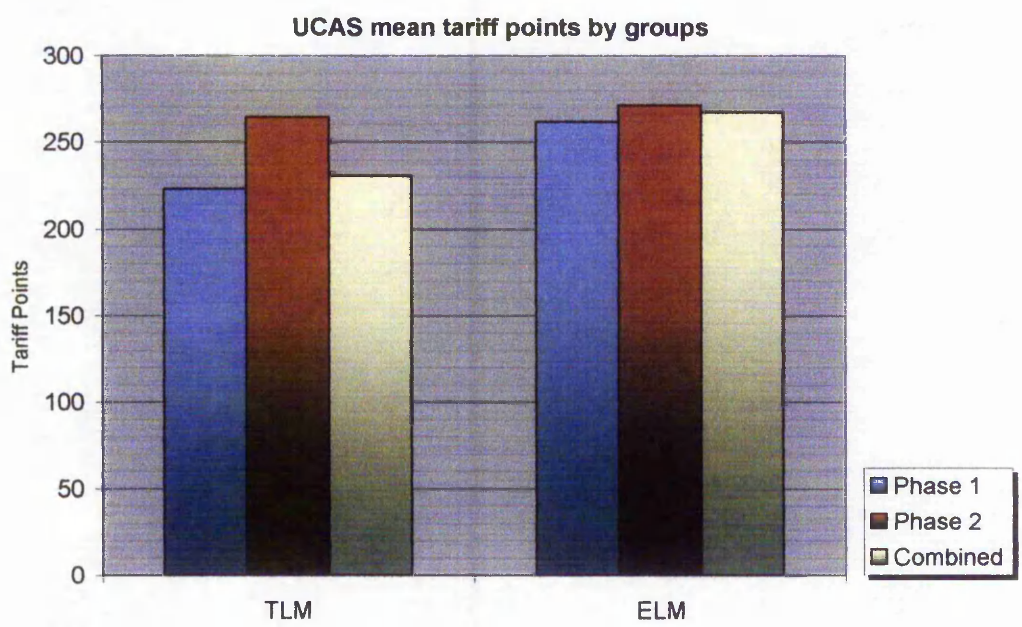


Figure 5.2 mean UCAS tariff point scores for each of the experimentation groups across both of the phases. Also illustrated is the combined difference between the groups.

Phase one – Year 2003/2004 students UCAS university entry tariff points.

No. of participants	**98**
Mean	**233**
Standard Deviation	**98.2**
Variance	**9638**

Phase two – Year 2004/2005 students UCAS university entry tariff points.

No. of participants	**53**
Mean	**269**
Standard Deviation	**84.3**
Variance	**7102**

Table 5.1 statistics regarding the UCAS tariff point scores for the participants of each of the phases of experimentation.

The UCAS tariff system (full details available at http://www.ucas.com/candq/tariff/index.html) was used to assess the students' entry qualifications into university. This system allows for a multitude of qualifications to be accepted, each qualifications representing its own number of tariff points, e.g. A'level, A/S level, B-Tec, NVQ's, etc. The UCAS tariff points allow for a profiling of the students learning ability and are considered to be a significant confounding variable in the experimental process that must be accounted for. Tariff point results were not available for all of the participants. However, 71 out of 92 (77%) tariff point results were analysed for phase 1, and 46 out of 59 (78%) in phase 2. The analysis of the quality of student participating in the experiments is therefore taken as a general overview of each experimental group of participants. Improving the accuracy of the profiling was attempted by examining the performance of the student in their first year of studies at the Nottingham Trent University. This examination was abandoned, as it was not possible to gather accurate comparable data due to the

2004/05 student intakes module and course structure being altered from that of the 2003/04 students.

Figure 5.2 and table 5.2 clearly indicate that participants in phase two of the testing were academically more qualified students than the students partaking in phase one. Not only are the mean UCAS tariff points greater but also the standard deviations of the results was significantly lower. Table 5.2 examines the UCAS tariff point difference between the students participating in the TLM experiments and those participating in the ELM experiences.

TLM experiment group – students UCAS university entry tariff points.

No. of participants	**92**
Mean	**230.5**
Standard Deviation	**89.5**
Variance	**8007**

ELM experiment group – students UCAS university entry tariff points.

No. of participants	**59**
Mean	**267.1**
Standard Deviation	**99.1**
Variance	**9830**

Table 5.2 statistics regarding the UCAS tariff point scores for the participants of each of the experimentation groups.

Students participating in the ELM experimentations were seen to have greater UCAS tariff point scores than the TLM students representing a 16% higher average university entry grade. From this it may be inferred that a bias with regards general academic ability was present in the ELM group. To what extent this ability affects the learning process and the effectiveness study is very difficult to ascertain. However, it is widely accepted that general and specific intelligence are major factors influencing knowledge building and learning abilities as stated in Gardner's (1993) theory of multiple intelligences; Fetherston's (1998) social cognitive framework & Hede's (2002) Integrated model of multimedia effects on learning.

Figure 5.3 displays a summary of the pre-test results. Full results may be found in appendix H. Illustrated below are mean scores from phase one and phase two of the traditional learning material experimentations and the electronic learning material. Grouping and comparing the results in terms of learning material type it may be observed that both phases of results correlate closely with one another. The results from both phases of the experiments differ by 2.6% for the traditional learning material with mean scores of 22.1% and 24.7% respectively being obtained. For the electronic learning material a mean score of 26.8% and 29.0% was recorded, differing by 2.2%.

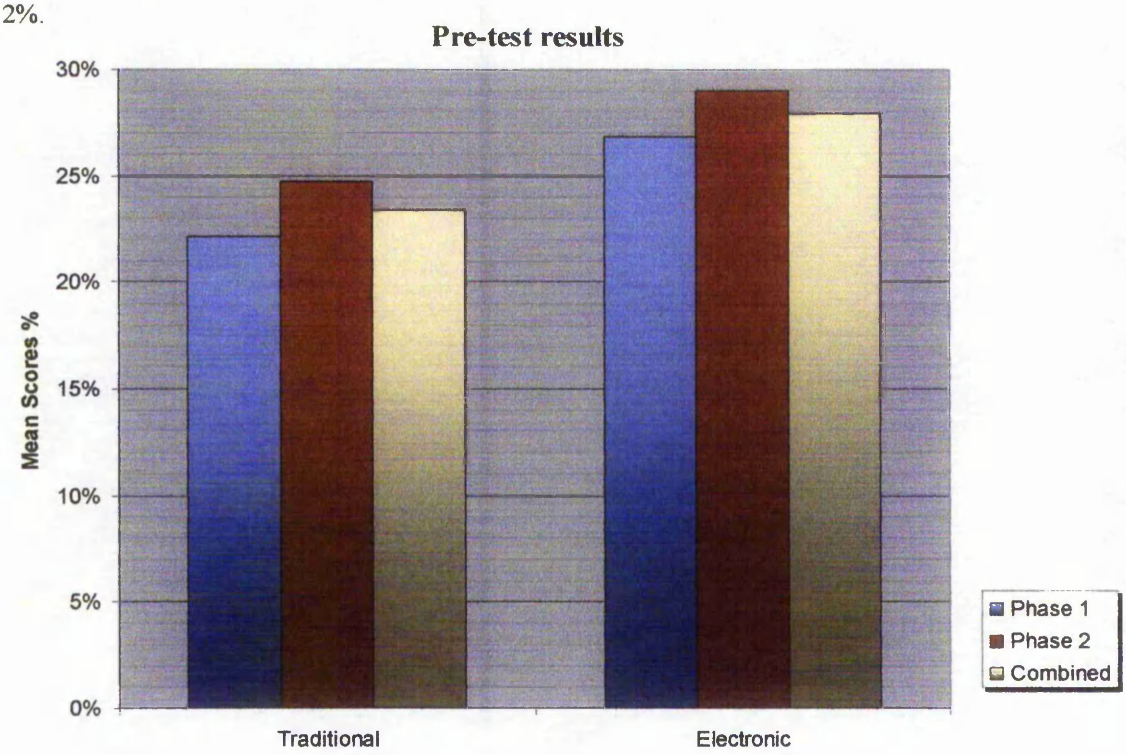


Figure 5.3 the pre-test percentage scores for both the traditional learning material package and the electronic learning material package.

A small difference in the mean scores of the pre-tests may be observed when comparing the two types of learning material against each other. In both phases the mean score of traditional learning results was recorded to be some 5% – 6% less than that of the mean scores of the electronic learning material. According to constructivist learning theory, learners possessing a higher degree of prior knowledge of a subject matter are expected to learn more effectively than learners with less prior knowledge. It therefore may be deduced that the student participants of the ELM group once more carry a bias in the effectiveness study conducted due to them on average scoring higher in the pre-test scores compared to that of the TLM group.

During the refining of the experimental process a revision to the post-test was made. This enhanced the post-test by including a number of additional assessment questions to obtain an improved evaluation of the participants post knowledge of the subject. Assessment weighting for this post-test was subsequently revised to evaluate in greater depth the participants understanding rather than being more biased towards visual recognition of physiological elements (see design specification). The differences in post test evaluation assessment need to be taken into account when discussing the accuracy and significance of the result. However, as differences between pre-test and post-test scores are presented as percentage differences rather then marked scores, an attempt at a comparison between the results from phase 1 and phase 2 was still deemed feasible and forms part of the analysis later in the chapter.

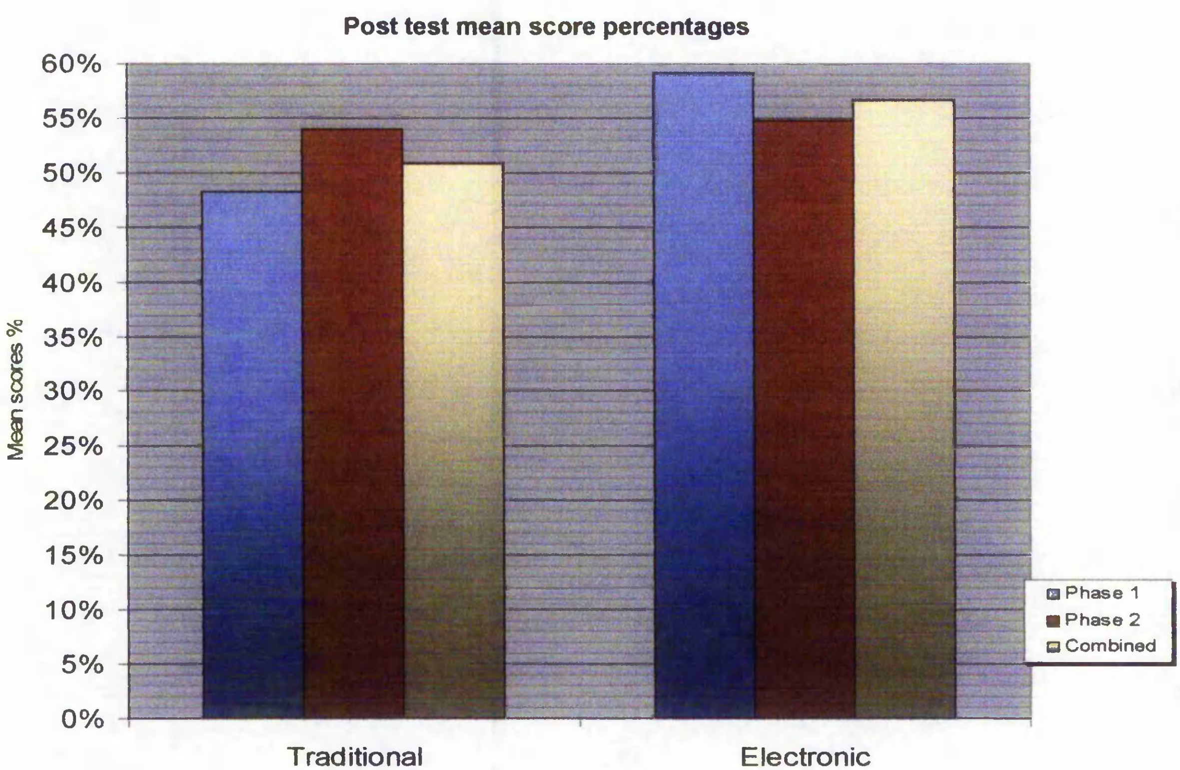


Figure 5.4 the post-test percentage scores for both the traditional learning material package and the electronic learning material package.

Figure 5.4 and table 5.3 display a summary of the post-test results and statistical calculations. Comparing the results of each learning material type it may be observed that the traditional learning material experiments results correlate closely with one another, displaying a 5.8% difference between phase one and phase two of the tests. During phase one 73 participants scored an average score of 48.2% in the post-test and 17 participants scored an average 54% resulting in a combined 90 participants averaging 49.4% after being exposed to the traditional learning material.

For the ELM experimental groups, 58 participants averaged a 56.6%. The results for the ELM were very similar in variance to the result of the TLM experiment group. Between the two sets of results a negligible 3% probability that the correlation of the variances in the mean scores was by chance.

Summary of post-test % results and ANOVA table for both phases of experimentations

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
TLM	**90**	**4501**	**49.22**	**321**
ELM	**58**	**3285**	**56.64**	**305**

ANOVA					
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Effect – Between Groups	**1550**	**1**	**1550**	**4.92**	**0.03**
Error – Within Groups	**45976**	**146**	**315**		
Total	**47527**	**147**			

Table 5.3 statistical tables for the analysis of variance within the post test percentage results. A summary and analysis of variance is presented. For detailed description of ANOVA tables please refer to Appendix K.

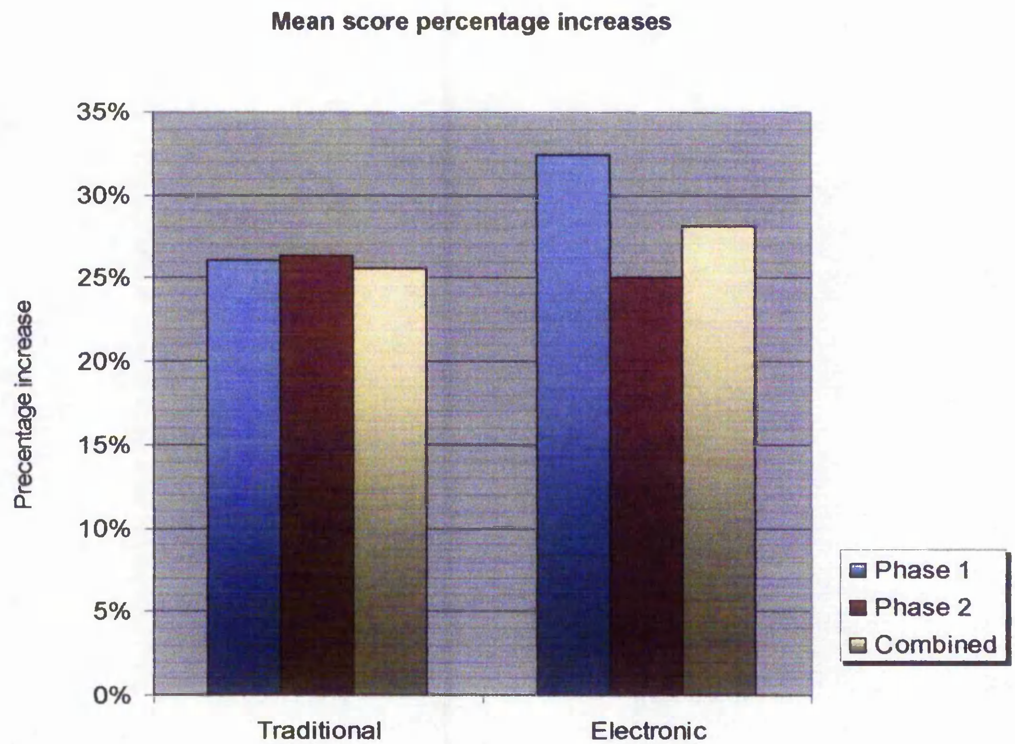


Figure 5.5 the mean percentage increases. The percentage increases have been calculated using the difference between the pre-test and post test mean percentage scores.

In figures 5.5 and table 5.4 the phase one result of the electronic learning material can be seen clearly. This mean percentage increase is unusually high. In this test group 25 participants obtained an average score of 59.1% and an average percentage increase of 32.4%. This result may be explained by the relatively small sample group of participants that were exposed to the ELM material during the phase 1 experiment. However, on examining the group's pre-test scores little supporting evidence is revealed that the group had significantly more prior familiarity with the subject matter, in fact the phase 2 ELM group averaged better on the pre-test. Analysing the groups UCAS tariff points scores against the ELM phase two groups reveals little evidence supporting the notion that the group had more academically suited participants. The averages are closely matched with other groups and variances not being significantly different. However, the group were observed to be a very studious group as compared to other groups that participated in the experiments and were very excited about experimenting with a multimedia learning package. This higher than expected result is hypothesised to be related to the group's motivation towards the learning experimentation. Being exposed to a social learning environment where behaviours of learners are influenced by others, as in this classroom environment, may have lead to an overall increase in motivational level of the whole group resulting in more effort, interest and ultimately learning occurring. Motivational factors and their impact on learning is discussed later in this chapter (see section 5.6 Further Discussions – Motivational influences),

Summary of % change results and ANOVA table for both phases of experimentations

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
TLM	**90**	**2352**	**26.13**	**347**
ELM	**55**	**1570**	**28.54**	**471**

ANOVA					
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Effect – Between Groups	**198**	**1**	**198**	**0.50**	**0.48**
Error – Within Groups	**53254**	**143**	**363**		
Total	**56452**	**144**			

Table 5.4 statistical tables for the analysis of variance within the percentage change results. The percentage change is calculated using the difference between the pre-test percentage score and the post test results. Appendix K has a general explanation of ANOVA and ANOVA tables.

Comparing the overall percentage increases of each of the experiments in both phases figure 5.5 & table 5.4 show combined percentage increases for the traditional learning material equating to 26.1% whereas combined percentage increases for the electronic learning material equates to 28.5%. Results obtained and calculated from both of the experiments favour the electronic learning material by a 1.8% difference.

This important result may be initially regarded as a rather disappointing one, as it seems that the electronic material demonstrates an insignificant advantage compared to the traditional learning material. Factoring in the financial cost and the increased development time needed to produce the ELM, the increase in effectiveness is deemed insignificant. This result quite clearly needs to be further analysed and discussed, specifically with regards the context and accuracy of the experimentation. This is done so in section 5.3 and onwards.

5.2 Questionnaire results (appendix J) and discussion

The questionnaire opened by requesting participants indicate whether or not they had previously experienced similar types of electronic learning material. 51% of students responded that they had previously used types of electronic learning material. 41% of participants indicated that they had previously used electronic material for learning on 3 – 4 different packages. Participants indicated that they had been in contact with this type of material mainly through the use of educational textbooks and encyclopaedias, software tutorials and driving theory exam. Interestingly 47% of participants indicated that the subject matter in these materials was associated with science, specifically biological material.

43% of these students had been exposed to similar material at school, 47% at home and 10% of participant's experienced similar material at their place of work. 87% of participants expressed a preference to using electronic learning material as opposed to the use of traditional learning methods. 8% of students expressed that they preferred traditional methods.

The students of the ELM test group were further asked to their opinion of the ELM material. 96% of participants considered the electronic learning material experienced to be effective with an effective rating of 67%, an interesting rating of 70% and a motivational rating of 60%.

From the questionnaire responses it may be stated that just over half of the students were familiar with the use of electronic learning material for teaching and learning purposes, more over, 51% of participants responded that electronic learning material, in their view, is more effective than traditional learning material. 31% responded that the learning material was neither more nor less beneficial than the TLM and 18% stated that TLM in their opinion is more effective. The main points the respondents to the questionnaire put forward gave rise to some interesting discussion and some key issues involved with multimedia and electronic learning, the points are as follows:

"Reading requires more use of brain; easier to take in information when not required to read".

This point raised is very true and a common issue for learners that have difficulty in reading or are particularly slow/poor readers. More over, learners whom are specifically learning challenged, such as dyslexic learners, often consider electronic learning material more favourable and effective for them than traditional text based material. Individual variables that influence ability to read are: intelligence, motivation, physiological, psychological traits and deficiencies in vocabulary and comprehension levels required by the particular reading material. This point leads on to discussions about learning styles and individualising learning experiences for each learner and their learning style. This will be discussed in the next section.

"Paid more attention; visually stimulating material that maintained interest and concentration."

This comment raises a point that some consider one of the major advantages of electronic learning material. Somewhat widely ignored previously in multimedia research, motivation significantly influences learning resources and plays a major role in determining the learning outcomes of any instructional material. Motivation is being recognised more so as an important factor, one that must account for much of the confounding results plaguing multimedia research to date. Recently (Astleitner, H and Wiesner, C 2004) models for advancing the research of the motivational factor and guidelines for instructional designers are being devised that attempt to account for the learners motivation variable.

"Easier to grasp information, advantage of seeing real life objects normally not accessible; not too good if wanting to look up a small piece of information; Far more interesting than reading a book".

The power of multimedia. Allowing one to view an abstract structure or gain a unique perspective on a process. It is this facet of multimedia that allows for learners to easily visualise or build mental stories allowing for deeper and clearer understanding of complex subjects. Further assisting in retention and allowing for the important steps of information processing from working memory to long term storage to be taken. The learner comments on a negative trait associated with the electronic learning package and importantly emphasises that not all electronic learning materials are appropriate for all learning needs. Electronic learning packages should not be viewed as a "one stop shop" for learning nor should electronic learning be deemed as a means of replacing traditional learning techniques and methods. A view of enhancement and an offer of an alternative is more favourable. This comment is also a little superfluous as the electronic learning material used in these experimentations was not designed for such a requirement. For small pieces of information a learner would look at other references that are designed to be easily and quickly accessed such as encyclopaedias.

"No distraction from learning environment; Clear and precise information presented".

An advantage of immersive environments that allow for the learner to cut off from the outside world and envelop themselves in the task at hand. This envelopment increases concentration levels that impact directly on how effectively a learner learns. Extraneous input, be it auditory or visual, lowers concentration levels and can lead to frustration of a learner. The clarity that this particular learner refers to is the clarity in design and presentation of the learning material. All types of instructional material may be designed for instructional effectiveness dependant on the learning strategy. In the case of this learning material the main instructional strategy is informational transfer. Designing the information in a clear and precise manner was an essential design consideration.

"Relaxed atmosphere it promotes; adequate time left between receiving information to digesting it".

The relaxed atmosphere noted here is the result of the background music accompanying the learner throughout the learning material and another outcome of the isolation from the learning environment. The background music chosen to accompany the learning narration and animations was a classical piece by Barber named "Adagio for strings" and is a well known relaxing musical composition. Research on whether background music is a hindrance or an aid to learning dates back to the 1930s (Fendrick, 1937, as referenced in Koppelman & Imig, 1995). Recent studies on this topic have concentrated on different aspects of learning, ranging from reading comprehension to writing ability, from mathematics problem solving to on-task-performance in science classrooms. Some have been small-scale observational studies undertaken in the natural classroom setting, while others studied children in relatively sterile laboratory conditions. Subjects have encompassed all age ranges from play school to university level, and results have been just as varied. Many studies have looked at non-computer task completion while listening to background music in a real-world setting. According to a study completed by Hallman, Price, and Katsarou (2002), calming music led to better participant performance on an arithmetic task and a memory task than no music. It was also found that background music on cognitive test performance led to improved performance when compared with a control condition (Cockerton, Moore, & Norman, 1997). Arkes, Rettig & Scougale (1986) found that as a task increased in complexity, listeners preferred music that was simple. The Mozart Effect (Rauscher, Shaw, & Ky, 1993) is a well-known phenomenon that showed that participants who listened to Mozart performed better on spatial tasks. A major factor whether or not background music is beneficial to learning is determined by learner preference. A piece of music that the learner dislikes can trigger a negative effect that dominates over any possible positive factors. Due to this when background music is used in a learning situation, especially within multimedia learning, the choice of whether the learner experiences the music should be available.

The respondents' comments regarding "adequate time left between receiving information to digesting it" are interesting if somewhat controversial. Looking at another comment "Very visual; 3D images and motion helps understand movement; Difficult to take in all information whilst playing" illustrates that the issue of pace within a learning programme is important to the learner, key to the effectiveness of the learning programme and extremely subjective. The pace of a learning programme needs to be suited to the learner and is a factor that is difficult to build into multimedia learning programmes relying on audio narration as the pace is set by the narration.

The design of the electronic learning material required that all students listen to the entire script of audio clips in a specific order and in its entirety. This suggests that audio imposes a set pace on a learner that may not be appropriate for the learner. This is similarly the case with face to face tuition, such as a traditional lecture. Lecturers find it difficult to gauge at what speed to deliver information. In other studies (Beccue, Vila, Whitley 2001) many students suggested that the audio imposed a slower pace than they were used to following. Some students needed to work at a faster pace than the audio could provide, while others took advantage of the ability to repeat individual clips. This suggests that audio imposes a set pace on a learner that may not be appropriate for the learner. Based on this it is theorised that the pace set by audio might be helpful for slower learners and detrimental to fast learners who want control of their learning environment. A high pitch, and fast pace causes excitement and tension, while a low pitch and slow pace causes confidence and relaxation (Daniels, 1993). Choices must be made and audio orchestrated to fit the setting of the electronic learning material. Moreover, as stated by the interactivity principle (as mentioned in chapter 2.3.3) multimedia messages result in better transfer when learners are able to control the pace of the learning material. Fast forwarding the spoken words is not an option for the learner as this would effect the pitch of the narration or if altered dramatically lead to a lost of information. One possible solution is the present words on screen as text enabling for the learner to quickly glance over the information, however, this also can lead to problems associated with the principle of redundancy, as Mayer and Clarke (2003) coin it (see chapter 2.3.3), overloading of the auditory channel (Mayer 2001) and Paivio's (1971, 1991;) dual coding theory. As with the first respondents comment, this is issue relates to learner style and personal preference and is discussed further in the next section.

5.3 Factors influencing results

As mentioned previously ('TLM Experiments' section in chapter 4), in the case of the traditional learning material the main factor that affected the participant's ability to learn was the differing quality in reproduction of the learning material. Also recorded was the fact that the poor reproduction affected the four groups participating in the traditional learning material experiment, this equates to 90 participants, 60% of the total number of participants taking part in the experiments. In an attempt to quantify the influence of this factor on the results, it has been deduced that only 20% of the information presented in diagrammatical form was unclear and of the 20% only 25% could be deemed as crucial to the context and hence have an influence upon the learning of the participant. The diagrammatical information was derived (again estimating and calculating conservatively) to constitute a maximum of 50% (in most cases considerably less) of the information presented within the learning package. Therefore it is calculated that the TLM participants' marks may have been affected negatively up to 2%.

As mentioned previously ('ELM Experiments' section in chapter 4), in the case of the electronic learning material experiments the main factor that affected the 55 (40% of the total participants ability to learn from the material was technical problems associated with the delivery of the electronic learning package running on poorly performing systems. Minor and major user frustration was observed and recorded in a number of circumstances. Most commonly experienced problem was the unacceptable long loading times of the material. This lack of performance also led to stuttering of audio narration playback and synchronisation problems between audio and visual material. Additionally, some systems were inoperable. These problems caused direct and indirect influences on the experiment. Firstly, the audio narration and synchronisation errors leading to incomprehensible narrated information that had a direct influence on the participants learning. Indirectly non-synchronised material is understood to lead to problems associated with the temporal continuity effect (see chapter 2.3.3). System problems impacted on the motivational influence of the electronic learning material resulting in a negative influence that counter acted the positive influence of the novel learning experience. Furthermore, some timing issues resulted from systems being inoperable and saw students hastening their post test assessment to finish on time with their colleagues. Due to the random nature of these errors calculating to what a degree these issues affected the participants' ability to learn from the package and ultimately on the post test outcomes is difficult to quantify.

What may be quantified is the number of errors within the package itself. During the phase 2 of the ELM experiments the first group found that approximately 10% the audio narration was unintentionally cut mid way through an explanation of a process/certain physiological element or missing entirely. These errors mainly affected the audio narration, however, in some instances absence of text cues was also reported. These two modes of transfer are considered to be major elements of multimedia based learning package (S. Craig, B. Gholson, et al. 2002) more so in this particular electronic learning material, where these two modes were being investigated and formed the basis of information transfer of the material. These errors were the cause of improperly carried out process of production and generally overlooked authoring errors. These errors are inherent in prototype applications where thorough testing, correction, retesting and correction has either been hastened or improperly conducted. The former being applicable in this case.

Most participants taking part in the experiments were students that were comfortable with using computers as they were all students from a computer based course, the Nottingham Trent University's Multimedia course. With regards a universal adoption of the results, motivation towards the electronic learning material does not suffer from a negative impact that it may with other participant; particularly those participants that have little, or not as well developed computer confidence. These participants may find using electronic learning material on computing equipment daunting and consequently influence the learners' motivation negatively. Examples of this can be seen in the profession of nursing where a cultural reluctance exists on the part of many female nurses to embrace technology in their roles as nurses. This reluctance stems from a feeling of "not being in control" of the technology (Wishart & Ward, 2002) where some "find it difficult to master switching on their computer" let alone engage in more adventurous actives such as email or the internet. Additionally, a socialisation process involving a "male" computer culture also affects the willingness of females to embrace such technologies (Brosnan & Davidson, 1994) which may, in part, be attributable to the quality of the previous training experience in information technology that women have had (Bernstein, 1991). This counteracts many researchers' beliefs that employing electronic learning materials increases motivation and in itself justifies endeavouring with such material. This view does hold some truth however, is entirely dependant on the individual and therefore should be treated with care.

The evaluation process made use of a post test that was formed using material from the traditional learning material. It must be highlighting that the post test contained a biased that resulted from an oversight at the design stage. The post test assessment was comprised of diagrams that were included within the traditional learning material and within the electronic learning material. However, participants of the ELM experiments had only a relatively brief time to examine this layout of the structure whereas the TLM participants had the opportunity to study the diagrams for relatively as long as they desired. The physiological structural information in the ELM was presented in addition to the exact diagrams in other forms for greater periods of time, however, not in the post tests identical form. This in hindsight favoured the TLM participants.

5.4 Extension of study

The entire research project fell short of some of its original objectives mainly due to the limited time allocated. It was originally anticipated that the project may compare various forms of electronic learning objects that were to be designed, such as a module retaining the visual information and detail from the optical based material (DVD/CD-ROM) that would be appropriate for web delivery. Experimentation with designing such material revealed the need for significantly more time to be spent realising these original objectives in learning other software techniques, authoring of the material and organising additional experiments on learners. Given time for the proposed material presented in figure 5.6, would allow for rich 3D animated models to be delivered via the web and allow for increased ease of distribution and ultimately realising the goal of on demand, just in time learning discussed in the review chapter.

In addition to the web delivery learning objects it was originally hoped (however not realistically accepted by the director of studies) that further work examining the effects of converting the material into full scale stereoscopic material that could be used for learning would be attempted. Utilising the Nottingham Trent University's newly installed large scale fully immersive stereoscopic installation, some preliminary work was done on rendering full scale stereo 3D animations and models that was mainly used for demonstration purposes, however, as correctly advised, no time was available for learner experimentation.

Proposed web delivered material

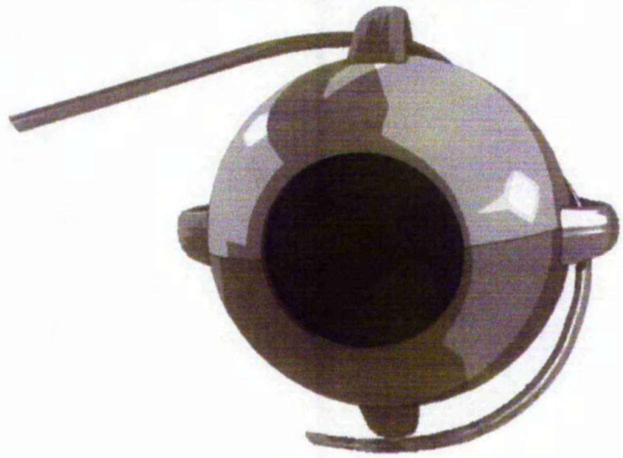


Figure 5.6 screen shot of the proposed web deliverable 3D rich learning material. With file sizes of around 300KB per animation this type of material would be appropriate for web delivery. This material was created in the flash open file format.

The electronic learning material in its current state may not be considered as learning objects, learning objects are defined by their small, size, reusability, ease of discovery by implementing metadata and consequently adding meaning, however, if broken down into "bite sized" block of information the material presented could be easily converted into a modules worth of learning objects.

5.5 Limitations of study

On examining the research study, a number of limitations maybe highlighted. One of which was the misconception that ADDIE was the instructional design model to be used when developing electronic learning material.

The generic form of instructional design, found at the core of most current models, is the ADDIE model – Analysis, Design, Development, Implementation, and Evaluation (Gagné, Wager, Golas, and Keller, 2005; Reiser and Dempsey, 2002). As stated in the design specification (Chapter 3), the ADDIE model focuses on learner performance relating to real-world tasks and its characteristics make the ADDIE model appropriate as a starting point for the development of electronic learning. With a vast number of references to it on the internet (a Google search reveals more than 32,000 hits), in textbooks, journal articles in conference presentation and in professional discourse, this modelled was portrayed as generally accepted and employed throughout the research project. However, the ADDIE model lacks focus and is the source of a great deal of confusion in the field of instructional design. ADDIE has been criticised because of its ineffectiveness and inefficiency (Gordon and Zemke, 2000), the fact that it does not take advantage of digital technologies that allow for a non-linear approaches to instructional design (Tripp & Bichelmeyer, 1991) is out of date and does not even reflect the real work of instructional design (Rowland 1993). Further, confusion and uncertainty surrounding the validity of ADDIE as an accepted model for instructional design is confounded by the lack of an original reference for the ADDIE model. Professor's Molenda's article 'In search of the elusive ADDIE model' (Molenda 2003) highlights that there is no original reference for the ADDIE model leads Molenda to concludes that "ADDIE exists as a label rather than as an actual ID model that is used to describe a systematic approach to instructional design". The ADDIE model is actually accurately referred to as a conceptual framework that is criticised for ignoring the learner, lacking descriptions for story, content, engagement and emotion:

"A great instructor touches the students emotionally. He or she grabs them—not just in the mind, but in the belly... emotion increases the likelihood that students will be able to transfer the knowledge and use it in a real-world setting". *Allison Rossett, Professor of educational technology, San Diego state university.*

"Logical structures tend to be very dull and boring—students have no idea why they're learning it; you don't work to retain information that's just given to you. When someone works at getting the information, they structure that information in their head so they can find it later. Basically, you remember what you care about". *Don Norman, Professor of computer science + psychology, Northwestern university.*

An opportunity for investigating learners' spatial abilities and personal learning styles against the measured learning outcomes was overlooked. Significant current research (Huk, T. Steinke, M. Floto, C. 2003 & Koroghlanian, C. Klein, J D. 2004) has focused on the issue of spatial ability and how this influences on how learners learn from general learning material, but more currently from electronic or multimedia learning material. Learning styles of learners and how the use of different instructional messaging principles affects the individual learners (as reviewed in chapter 2.3.3) has also been an area of particular research interest over recent times (Hong, H., Kinshuk, D. 2004 & Kumar, P., Kumar, A., & Smart, K. 2004). Not including these key variables in the evaluation processes investigation of associated hypotheses, comparisons of existing research data and possible discussions of influences on the results gathered further limited the research study results. These current issues within the field of instructional design were not brought to light to the author in time for inclusion within the experimentations thus these factors were not included as experimentation variables during this research. Although the feasibility of including these variables would have been needed to be investigated further, as additional variables would have complicated the experimentation requiring all participants to be tested for learning style and to be grouped with regards learning styles. Logistically this would have also been complicated as well as with regards to research methods in analysing the subsequent results.

The experimentations failed to produce the desired number of results for the ELM groups. 92 students took part on the TLM experiments and only 59 took part in the ELM. This was partly due to a large group of students being tested during phase one of the experimentations that was pre assigned to the traditional learning package experiment. Due to the complexity of producing the electronic learning package and a limited time frame the ELM package was not available for testing as early as hoped. Subsequently, only the last group of the three test groups available for testing was tested using the ELM package in phase 1. Compounding this effect was the fact that during phase 2 of the experimentations only half the students were present to take part in the experimentations. This further impacted on the variability of numbers tested for each of the packages. In hindsight relying on phase 2 to make up for the lack of phase 1 ELM results was a mistake, even if logistically difficult, emphasising the importance of the seminars to the students may have produced a larger demographic response.

The UCAS tariff point system used in collecting data was the only available way of assessing the students learning abilities, however, this data was not complete and variations may have existed. Attempts at gathering the missing data were made, but it was advised, by the director of studies, that these be withdrawn due to sensitive nature of the data. It is therefore not possible to conclude whether the ELM participants could have in fact been better quality students and difficult to determine which set of results is most accurate.

5.6 Further discussion

The research results do not produce a clear conclusion or significant difference in the effectiveness of the ELM over the TLM. However, it may be stated that the ELM is as effective as the TLM, which may be considered a result in itself. Comparing the ELM experiments in the context of the interactivity principle, as discussed in chapter 2.3.6, it may be highlighted that the ELM package did not offer learners an option of controlling the pace of the learning, a facet that is of great importance in any self study package (Olkinuora et al 2004).

As figure 5.7 shows, if the external control (strong regulation by the learning material or by a teacher) in instructional condition is strong and students possess a high level of self-regulation skills, or are use to instruction that presupposes it, a destructive friction may arise with harmful consequences for high-quality learning. On the other hand, if the degree of material-based

Interplays between three levels of teacher/material-regulation and three levels of student-regulation of learning processes

Degree of student regulation of learning	Degree of material/teacher regulation of learning		
	Strong	Shared	Loose
High	Destructive friction	Destructive friction	Congruence
Intermediate	Destructive friction	Congruence	Constructive friction
Low	Congruence	Constructive friction	Destructive friction

Figure 5.7 comparison table of the interplay between material / teacher regulation and the preference of learner regulation (after Vermunt and Verloop 1999).

regulation (or of teacher-regulation) of learning is low and the readiness of students for self-regulation is high, they are in congruence with each other and the process of learning is probably effective. Even though material regulation within the ELM package was strong due to the pace set by the audio, the results obtained were comparable to those obtained from the participants experiencing the TLM package, where the degree of material regulation was relatively loose. With an equivalent effectiveness of the learning material to traditional methods of self study the positive facets raised by the participants during the feedback forms and questionnaires of the ELM may be considered significant factors in enhancing the effectiveness of electronic learning material and multimedia learning material. One of the main facets that were identified was the effect that the ELM had on participants' motivation towards learning. As noted by 60% of participants in the ELM research experimentations, motivation towards the learning material and more generally towards the learning experience was positively influenced.

This issue is postulated by many researchers, Hidi, S., & Harackiewicz, J. M. (2000) in 'Motivating the academically unmotivated', Hede (2002) in his 'Integrated model of multimedia learning' and a follow up by Astleitner, H., & Wiesner, C. (2004) 'An integrated model of multimedia learning and motivation', motivational factors are critical for establishing a multimedia as a learning platform. Motivational factors typically have not been taken into consideration in cognitive based learning theory. A prime example is Mayers (2001) well founded and widely recognised theory of multimedia learning. Mayers' theory does not include motivational factors. Some aspects of a multimedia learning experience also have a non-cognitive quality, an example is given by Tang & Isaacs (1993), where video information is evaluated as having a greater motivational value than audio information, because it integrates appealing dynamic pictures, colour, etc, that give learning support and help to reduce the fear of failure. Harp and Mayer (1997) distinguished between "cognitive interest", based on structural coherence and "emotional interest", based on attention and curiosity that may be triggered by different multimedia elements. However, motivational elements of multimedia learning should not be ignored for several reasons:

1. Motivation influences learning significantly.
2. Motivational processes need memory resources and therefore increasing or decreasing cognitive load.
3. There is a more or less a direct connection between cognitive and motivational variables: especially attention represents an important element, both for cognitively and for motivationally driven models of learning.

Astleitner (2004) proposes a possible solution to the two views of cognitive and emotional interest by suggesting that a theory which integrates cognitive and motivational aspects of memory usage and learning is found and used.

Stated by Astleitner are two main questions that will be important for future research and instructional design. The questions dealing with the phenomenon of “seductive details” and the other dealing with “motivationally adaptive” mechanisms. “Seductive details” distract a learner or disrupt the coherence of a learning process and need to be clarified in future research to what extent motivational strategies in multimedia are seductive and how strategies can be implemented in multimedia without producing the risk of being seductive. For this there are three different predictions (Harp & Mayer 1997). Firstly instructional activities that are motivationally relevant may increase motivation but decrease learning by taking the learners attention away from important information – “distraction hypothesis”. Secondly, by interrupting the transition from one main idea to the next – “disruption hypothesis”. Thirdly, by building a coherent mental representation but not of structurally important ideas – “diversion hypothesis”. The second main research question should deal with the issue of how multimedia can be made “adaptive” to different types of learners and their needs. Adaptive multimedia with regards task difficulty where the tasks are both difficult enough to support cognitive learning and knowledge acquisition, but not too taxing as to impact on stimulating motivation. Adaptive multimedia with regards preferred presentation type, mainly considering learners with accessibility issues, and adaptive with regards pre testing learners and profiling them before selecting suitable learning.

6.0 Conclusions

6.1 Conclusions of research results

The research project has successfully attempted to analyse the pedagogical and instructional value of electronic learning technologies and in particular has highlighted the appropriateness of using multimedia in these electronic learning technologies. In this research, multimedia learning initially was understood to be the use of different media and how the differences in these media have an effect on learning. It became more apparent throughout this research that the question was not as valid as at first thought. There is a great deal of co-dependence among media components of multimedia learning and electronic learning in general and it is therefore difficult, if not impossible, to use empirical research to explore the different effects of any single factors on learning in general. This led the research to concentrate more specifically on examining the effects of how combining various instructional messages lends itself to producing effective learning material. Many multimedia researchers have also come to the conclusion that this media centred debate is unproductive and suggest different and more constructive debates, "in what ways can we use the capabilities of media to influence learning for particular students, tasks and situations?" (Kozma, 1994), "how instructional treatments affect cognitive processing in the learner rather than on the effects of media per se" (Jonassen, Campbell and Davidson 1994).

Limited by the exclusion of important variables in the pre coding of participants, the research results draw the conclusion that altering the combination of media that learning material is presented in, (that is, electronic based animation with audio narration and limited text labels, against traditionally presented text and diagram based material) does not produce any clear significant differences in learners learning outcomes or retention. However, it may be stated that many other positive effects such as the increase of motivation, the personal preference of some users to use multimedia learning methods to learn complex concepts and the lowering of cognitive load of these learners was recorded and observed. Rich multimedia resources empower learners with improved educational competencies, however, the sole use of multimedia effects in electronic learning courseware does not guarantee increased learning effectiveness. It is clear that many learners may yield authentic learning outcomes from an approach based upon a mix of sound cognitive psychology and instructional design principles.

The evidence of increased motivation towards the electronic learning material supports the view held by many researchers discussed in the previous chapter (5.6) and underlines the importance of motivation in the model of multimedia learning. Also supported is the view that using cognitive psychology principles augment instructional design and may be used by designers as guidelines for designing multimedia learning material.

Illustrated by the comparable results and in the views of the majority of participants in these experimentations, there are many benefits from incorporating multimedia learning into specific aspects of education and instructional design. Some of these benefits are immediately obvious. For example learners using multimedia learning material with high spatial abilities find that this learning method is advantageous to them to the learning experience that ultimately affects their learning outcomes. And some that are more subtle benefits, for example, the positive effect exhibited by those that are comfortable with using computer and multimedia equipment using an interesting and dynamic learning environment. Because constructivist theories regard learning as a process of extracting meaning from personal experiences, a lifetime of activities, memories, ideas and feelings will affect what and how an individual learns in any one situation. Learning is therefore a highly subjective issue, dependent on many more factors than the quality of learning materials, or the charisma of the trainer. Current trends seem to be focusing on the learner and their preferred method of learning. Theoretical models and frameworks discussed put the learner at the centre of the debates of learning methodologies and look towards giving the learner choice to what they learn from and how they learn. This ideal is however, as usually is the case, constrained by financial implications. Bespoke and custom designed learning is generally more expensive and time consuming to implement as is the complexity of adapting to learners personal preferences and learning styles.

Though Instructional Design may have a behaviourist tradition, new insights to the learning process continue to replace, change and alter the process. Advancements in technology make branched constructivist approaches to learning possible. Whether designing for training or education, the instructional designer's toolbox contains an ever changing and increasing number of theoretical applications and physical possibilities. With intelligent application of learning theory strategies and technology, the modern designer will be able to find increasing numbers of solutions to the learning requirements of the 21st century.

6.2 Future learning technologies and trends

To conclude the thesis several important trends that underlie the future developments of learning technologies are summarised. The likely impacts of these six trends for teaching and learning are significant and broad-reaching. Even more than their potential for the classroom, each of the trends is influencing the others in ways that continue to unfold. As they do, it is an almost certainty that new forms of communication, collaboration, and learning will follow. These trends and the areas that they are predicted to impact are described in the following section.

- Learners are not only willing to participate in the construction of knowledge; they are starting to expect to.

- New models for sharing and licensing content and software are emerging that will have lasting implications for the way information is distributed and obtained. Open-source software development projects are becoming more common. Forms of license that not only allow, but also promote the sharing of resources are on the rise. An example is the Creative Commons (www.creativecommons.org), a non-profit organisation that supplies flexible copyright statements for creative work.

- The lines defining what can be done with desktop computers as opposed to laptops, handhelds, or even cell phones are blurring. In response to consumer demand, device manufacturers and software producers are increasingly focused on interoperability and compatibility.

- Access to the Internet is increasing, not only in terms of who has it, but also in terms of what devices can do it. This trend, driven by the increasing demand to keep in touch and stay informed, is resulting in more possibilities for communication and information retrieval. Increased access is augmented by new developments in wireless technology.

- People are using technology to connect with each other easily, informally, and on many levels. This is one of the most interesting current developments in educational technology. The fear that technology-enhanced communication will replace face-to-face interaction is subsiding, replaced by a dawning understanding that enabling social interaction and interpersonal connections is a valuable aspect of technology.

- Content is valued over format, meaning that consumers are less concerned with where content comes from or how it is packaged and more concerned with what it actually is. This is resulting in content offered in a variety of formats, often with different costs associated with the various formats.

The technologies described below are framed within three adoption horizons. The choices in the first category, extended learning and ubiquitous wireless, are seen in use already at leading campuses across North America and Europe. Applications for both can be expected to grow substantially within that time frame. Two additional technologies are spread along the two more distant horizons. All are seeing significant development in the private sector, but their applications for higher education are still unfolding. Each area poses interesting possibilities for teaching and learning, and early experiments with all of them seem quite promising. The consensus is that within the next two to five years, all four will see broad usage within colleges and universities (The Horizon Report 2005).

Extended Learning (Currently being adopted – one year or less to adoption)

On some campuses, traditional instruction is augmented with technology tools that are familiar to students and used by them in daily life. Extended learning courses can be conceptualised as hybrid courses with an extended set of communication tools and strategies. The classroom serves as a home base for exploration, and integrates online instruction, traditional instruction, and study groups, all supported by a variety of communication tools such as instant messaging, blogs, RSS Wikis. Students also carry mobile phone, PDA's, laptops, iPods and other small devices.

Ubiquitous Wireless (Currently being adopted – one year or less to adoption)

With new developments in wireless technology both in terms of transmission and of devices that can connect to wireless networks, connectivity is increasingly available and desired. Campuses and even communities are beginning to regard universal wireless access as a necessity for all. A new generation of broadband wireless technologies, including 802.11n and 802.16 (WiMAX), is emerging that will continue to support the trend of ubiquitous wireless access. Both technologies significantly increase both throughput and reach of the standard wireless mobility experience, with a single transmitter being capable of covering a 3 – 30 mile radius (depending on number of users), providing faster, more cost-effective access while requiring fewer transmitters. Ubiquitous wireless would give rise to ubiquitous m-learning and provide the means of enhancing social dynamics.

Intelligent Searching (Two to three years till adoption)

To support people's growing need to locate, organise, and retrieve information, sophisticated technologies for searching and finding are becoming available. These agents range from personal desktop search "bots," to custom tools that catalogue and search collections at an individual institution, to specialised search interfaces like Google Scholar and Google Suggest. The implication for researching is clear, advanced search agents that are customisable and autonomous will simplify finding sources and collecting information, checking facts, building bibliographies, connecting people or organisations working on similar projects. Intelligent searching agents are additionally aiding collections and resource lists for similar courses to grow over time as new material is produced and ensuring the course content is cutting edge and up to date. The emerging Semantic Web, already discussed earlier in the previous section, will provide a standard and all encompassing network for intelligent searching agents to operate.

Context-Aware Computing / Augmented Reality (Four to Five years till adoption)

These related technologies deal with computers that can interact with people in richer ways. Context-aware computing uses environmental conditions to customise the user's experience or options. Augmented reality provides additional contextual information that appears as part of the user's world. Goals of both approaches are increased access and ease-of-use.

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Appendices

Appendix A – List of key organisations involved in e-learning

AACE - Association for the Advancement of Computing in Education
http://www.aace.org/default.htm
The Association for the Advancement of Computing in Education (AACE), founded in 1981, is a US-based, international, educational, and professional organisation for the advancement of the knowledge, theory, and quality of learning and teaching with information technology. It encompasses SITE, the Society for Information Technology and Teacher Education. AACE sponsors the SITE, Ed-Media, and E-Learn international conferences. The AACE Web site includes news items, an online forum, a listserv, a job board, and a publications section. AACE publishes six journals about e-learning; these are available in hard copy only. The Web site also contains links to two e-journals that AACE publishes in partnership with other organisations.

ALT - Association for Learning Technology
http://www.alt.ac.uk/
ALT (the Association for Learning Technology) is an educational organisation that aims to bring together all those with an interest in the use of learning technology in higher and further education. ALT's goals are to promote good practice, to represent its members in areas of policy, and to facilitate collaboration between practitioners and policy makers. The ALT Web site contains news, issues of newsletters, publications, conference abstracts, a links page, and information about events and workshops. ALT also publishes ALT-J, a print journal about learning technologies in tertiary education.

Archives of ELEARNING@JISCMAIL.AC.UK
(elearning projects group: museums and galleries, libraries and archives)
http://www.jiscmail.ac.uk/lists/ELEARNING.html
JISCmail is a mailing list service sponsored by the JISC for the UK Higher and Further Education communities, enabling members to stay in touch and share information by e-mail or via the web. JISCmail is based on a Listserv system, which is hosted and run by a dedicated team at the CCLRC's Rutherford Appleton Laboratory. This list is to share ideas and best practice in e-learning projects in museums, libraries, archives, galleries and HE/FE organisations

Archives of EVALUATION-OF-ONLINE-LEARNING@JISCMAIL.AC.UK
(Evaluation of online learning)
http://www.jiscmail.ac.uk/lists/EVALUATION-OF-ONLINE-LEARNING.html
JISCmail is a mailing list service sponsored by the JISC, for the UK Higher and Further Education communities, enabling members to stay in touch and share information by e-mail or via the web. JISCmail is based on a Listserv system, which is hosted and run by a dedicated team at the CCLRC's Rutherford Appleton Laboratory. This list is designed to support action research in the development of tools to evaluate learning in online virtual environments.

Archives of NETWORKED-LEARNING@JISCMAIL.AC.UK
(Networked Learning in Higher Education)
http://www.jiscmail.ac.uk/lists/NETWORKED-LEARNING.html
JISCmail is a mailing list service sponsored by the JISC, for the UK Higher and Further Education communities, enabling members to stay in touch and share information by e-mail or via the web. JISCmail is based on a Listserv system, which is hosted and run by a dedicated team at the CCLRC's Rutherford Appleton Laboratory. The Networked Learning in Higher Education list is run by the Networked Learning in Higher Education team at Lancaster University's Centre for Studies in Advanced Learning Technology (CSALT). The list covers networked learning, online learning, e-learning, web-based learning, etc.

British Learning
http://www.british-learning.com
British Learning aims to connect people, methods, and new ideas for learning. The organisation's purpose is to build a dynamic community, with global reach, committed to innovation, excellence, and best practice in learning. British Learning publishes a hard copy journal, 'Open Learning Today'. The British LearningWeb site contains news, information on learning centres, a job bank, a comprehensive section on resources and guidelines, an extensive links section, and a searchable online directory of products and services related to open learning.

brandon-hall.com
Your Guide to E-Learning
Brandon-Hall.com
http://www.brandon-hall.com/index.html
The Brandon-Hall.com Web site provides information about learning technologies in order to help users select the appropriate tools for their needs. The Web site contains information about trends, best practices, tools, and vendors. Resources such as white papers, discussion groups, research reports, product reviews, guidelines, and market analysis papers are available on the site, as are discussion groups and an e-newsletter. The site also contains a publications section with publications and videos available to be purchased. The publications include reports on LMS systems. Brandon-Hall.com also provides personalised consultations on e-learning.

mda
Building Digital Content
http://www.mda.org.uk/bdc_intro.htm
This short essay 'Building Digital Content: A Study in the Selection, Presentation and Use of Museum Content in Schools', edited by Sande Nuttall, is available on the mda Web site. The report addresses the issues of selecting content for digitisation, presenting the content in intelligible ways (including a basic introduction to creating an easily navigable Web site), and using the content in the classroom. The report aims to present a baseline for good practice, and especially to emphasise standards for educational content, for technical efficiency and for accessibility. It includes many examples of museum Web sites.

DEEP - Digital Education Enhancement Project
http://www.open.ac.uk/deep/
DEEP (the Digital Education Enhancement Project) is funded by the Department for International

Development (DFID) UK, and is a partnership between the Centre for Research and Development in Teacher Education at the Open University, UK, the University of Fort Hare, Eastern Cape, South Africa, and the Programme, Planning and Monitoring Unit of the Egyptian Ministry of Education in Cairo, Egypt. This research and development project is focusing on the use of new Information and Communications Technology (ICT) in primary schools in the Eastern Cape Province of South Africa and in Cairo, Egypt. The project's main research questions focus on the impact of ICT on learner achievement and motivation and teachers' pedagogic knowledge: What is the impact of ICT-enhanced and transformed strategies on pupil achievement and motivation? How does ICT transform the pedagogic knowledge and practice of teachers and the communities in which they work? The Web site includes initial research findings and professional development resources, as well as associated papers.

Digital Preservation Coalition
http://www.dpconline.org
The Digital Preservation Coalition addresses the challenges of securing the preservation of digital resources in the UK and works with others internationally to secure global digital memory. The site includes information on events, reports (including Technology Watch reports), news, and also includes a members-only section. It also provides access to the Handbook, a practical guide to managing digital resources over time and the issues in sustaining access to them.

Distance-Educator.com
http://www.distance-educator.com/
Distance-Educator.com, founded in 1995, is a Web site providing information to distance learning professionals. The Web site contains news items, publications, links to sites about distance education and other related issues, and a bibliography of selected readings, as well as a compilation of journal articles, reports, and other resources selected from various outside Web sites and organisations.

EdWeb
http://www.edwebproject.org/
EdWeb is a Web site written and produced by Andy Carvin, a researcher in e-education. The site is in the form of a hyperbook that includes discussion on the following topics: the role of the Web in education, the information highway, education reforms for the 21st century, and computers and kids. The site also includes an interactive crash course in HTML, a resource guide for K-12 education, and an online discussion group, as well as links to other sites about e-education.

E-Learning Central
http://elearningcentral.org.uk/
E-Learning Central is a Web site for users and developers of e-learning materials in the UK, particularly in further education. The site contains information about e-learning, a glossary, links,

and resources such as PowerPoint presentations, video clips, audio clips, and Flash movies. The site is affiliated with Becta, NLN (the National Learning Network), and Ferl.

e-Learning Centre
http://www.e-learningcentre.co.uk/eclipse/default.htm
The e-Learning Centre is a UK-based Web site that contains an extensive amount of resources on e-learning. The Web site includes a message board, a glossary, a job centre, a showcase of e-learning examples, an index of vendors with reviews of products, an index of e-learning events, and information on services that the e-Learning Centre provides. The 'Resources' section contains links to articles, white papers, research reports, journal articles, resource collections, and books about e-learning. There is also a members-only section (free to join), called eCLIPSE (e-Learning Centre's e-Learning Intelligence Service: People, Systems, and Environments). It contains a range of learning centres, highlights, and a monthly online newsletter.

elearnspace
http://www.elearnspace.org/
This Web site is intended for users, managers, developers, and facilitators of e-learning. The Web site stresses that many resources exist for e-learning, yet a model of how the pieces fit together is often missing. Therefore elearnspace has been organized to present a whole picture view of e-learning. The Web site is maintained by George Siemens, an instructor at Red River College in Winnipeg, Manitoba, Canada. The main goal of the Web site, as set up by its maintainer, is to make a series of resources available that developers, teachers, and managers of e-learning can use in completing their daily tasks. The second stage of the Web site will be to foster interaction (discussion questions, chat rooms, etc.), and the third stage to offer individual identity and discussion - moving elearnspace to the level of a "community".

University of Leicester

E-NEd at University of Leicester
http://www.le.ac.uk/cc/rjm1/ened/
This Web page from the University of Leicester contains an extensive selection of links to various topics concerning e-learning. Included are e-learning articles, demonstration Web sites, legislation information, and information on e-universities, learner support, key skills, and virtual learning environments. There is also a link to a discussion portal. The site also includes the project plan for E-NEd, an e-learning package for Nursing Students at the University of Leicester.

Evaluation Methods and Procedures for Studying Learners' Use of Media
http://iet.open.ac.uk/plum/evaluation/plum.html
This Web site, developed by PLUM (Programme on Learner Use of Media at the Open University) and TELL (Technology Enhanced Language Learning consortium led by the University of Hull), contains information about evaluation processes, types of evaluation findings and data collection methods useful for studying learners' use of media. It also includes some sample pro-forma documents, such as an observation report, monitoring program, evaluator's report, user evaluation checklist, etc. The Web site also provides an overview of evaluation of multimedia material and explains the formative and summative phases of evaluation.

Georgia Tech Research Institute - Evaluation Tools for E-Learning
http://mime1.marc.gatech.edu/MM_Tools/evaluation.html
This Web site from the Georgia Tech Research Institute (USA) offers evaluation tools suitable for

use at various stages of an e-learning project. Templates are available for download to assist with gathering both quantitative and qualitative data. The evaluation tools include: Evaluation Matrix; Anecdotal Record Form; Expert Review Checklist; Focus Group Protocol; Formative Review Log; Implementation Log; Interview Protocol; Questionnaire; and User Interface Rating Form. This resource would be useful for those designing an evaluation process for an e-learning project.

ICDC - International Centre for Digital Content
http://www.icdc.org.uk/
ICDC (the International Centre for Digital Content) is part of Liverpool John Moores University, in partnership with Mersey TV. It is funded by the European Regional Development Fund and the NWDA. The mission of ICDC is to create a strong digital content industry in England's Northwest by transferring the skills and knowledge from inside the organisation. ICDC is interested in how new technology can be applied in new and exciting ways, especially in the areas of interactive TV, 3G mobile solutions, broadband, gaming technology, personalisation and location based services. ICDC provides events, training, mentoring, matchmaking, research collaboration and incubation services. The organisation manages the Digital Academy project for Merseyside, focusing on 14-19 year olds and new ways of learning. The Web site includes information on ICDC's education, research, events, training and incubation projects.

Immersive Learning Space
http://www.accessart.org.uk/immersive_learning/ilplaunch.htm
The Immersive Learning Space is a digital resource designed to harness creativity in teenagers. The project, launched by AccessArt and funded by NESTA, asks the key question 'When, where and how does learning happen best?' The site champions the approach of 'active doing and seeing' and promotes the development of young people's creative, visual and spatial skills through physical and virtual exploration. It searches for new models to engage and motivate teenagers to use their creativity. The project has evolved through eenagers and creative adults partnering through workshops, brainstorming sessions, one-to-one conversations and the creation of the digital space itself. Immersive Learning Space provides schools, home-users and community groups with access to resources which engage children on their own terms.

Learning Lab
http://www.learninglab.org.uk/asp/homepage.asp?ses
The Learning Lab was established in 1999. It is a non-profit organisation providing impartial advice, information, a showcase of learning technologies and examples of best practice to any organisation wishing to engage in the deployment and strategic use of ICT in the education and training sector. Through independent research and collaboration, the Learning Lab aims to assist the education and training sector to move positively into the future by developing technology-based learning support structures. Through an annual conference & exhibition and regular seminars, the Learning Lab is able to address many of the questions raised by prospective users of technology. The Web site provides a thoughtful overview of the Lab's work, initiatives and events. It also holds a rich collection of resources (downloadable papers, useful links, case studies) and publishes a quarterly journal, which can be downloaded in PDF format. Users can register with the Learning Lab for Lab Updates and access to resources.

The Learning Space Online Teacher Network
http://www.learningspace.org/
The Learning Space is a teacher-based organisation that provides educators with opportunities and tools to develop, implement, and share effective uses of technology to improve student learning. The Web site allows teachers to share lesson plans and new ideas for incorporating technology into the classroom. It also offers training workshops for continuing professional development, a mailing list and connection projects, a lessons library, and a programme called Digital Blackboard that was designed to create new opportunities for students and teachers in at-risk communities.

MASIE Center
http://www.masie.com/masie/default.cfm?page=default
The MASIE Center, a US-based organisation run by technology and learning specialist Elliott Masie, is a 'learning and technology e-lab and think tank'. The MASIE Center provides its services to major corporations and technology providers throughout the world. The Center provides research, perspectives, training, learning products and consulting on issues of learning technology. The MASIE Center also hosts the TechLearn annual conference. The Web site contains resources such as articles, reports, handbooks, presentation slides, links, a weekly e-letter subscription service, and an online bookstore. It also has a list of members of the e-Learning Consortium, which is a group of major corporations, government agencies, and e-learning providers.

Museum Learning On Line
http://www.resource.gov.uk/action/learnacc/muslearn/start.asp
This document, created in 2001 by Peter Clarke for MLA (formerly Resource), explains museum learning and lifelong learning, examines various different models of learning, and illustrates how museum learning can be conducted online. It contains guidance for museums who are new to using the Web, a selection of familiar museum models and their online versions, and instructions for planning, creating, and evaluating an online learning resource. It also gives examples of good practice. The document contains many references to other resources.

NESTA Futurelab
http://www.nestafuturelab.org/
NESTA Futurelab is an initiative of NESTA (National Endowment for Science, Technology and the Arts). Based in Bristol, this think-tank consortium uses new and emerging technologies to create interactive learning resources through research, prototype development and communications. NESTA Futurelab acts as a hub to support the flow of information and knowledge between practitioners, policy makers, creators and learners. The organisation works with individuals, corporations, practising teachers, government bodies, academics and venture capitalists to support new approaches to learning and teaching. The Web site includes information

on new ideas, events, research, and a showcase of projects, and a viewpoints section with articles about digital learning.

Oxford Centre for Staff and Learning Development - Teaching and Learning Online: Some Resources
http://www.brookes.ac.uk/services/ocsd/4_resource/t&lonlin_eval.html
The Oxford Centre for Staff and Learning Development (OCSLD) has been situated at Oxford Brookes University since it began in 1989. Over the last ten years OCSLD has grown into one of the UK's largest providers of staff and educational development for higher education, with a reputation for innovation in learning and teaching. The Centre delivers up to 350 staff development events a year - drawing on a national network of over 35 specialist consultants. Within Oxford Brookes the ten development consultants of the Centre are responsible for both educational development and virtually all staff development activities supporting the university as an employer as well as a service provider. In this particular Web site, the Oxford Centre provides with resources for those interested in evaluation of online learning.

PLAN - Pervasive and Locative Arts Network
http://www.open-plan.org/
PLAN, the Pervasive and Locative Arts Network, is a new international and interdisciplinary research network in pervasive media and locative media. The network includes practicing artists, technology developers and ethnographers, and aims to advance interdisciplinary understanding. It is geared towards those working in the arts, games, education, tourism, heritage, science and engineering. The
network has planned three major gatherings in the next two years to support the research community and to generate new collaborative projects.

Rosalind
http://www.furtherfield.org/gestation/
Rosalind is a new media art lexicon designed for use by users of digital resources and art, which allows participants to submit their own words and definitions of terms related to net art, new media, psychogeography, online performance, real-time creativity, soft groups, writers, code geeks, curators, relationalists, activists, networkers, networked collectives, net activism, social networks, net mutualists, and more. Users are invited to submit words which describe their life, experience, work or net-based behaviour. The lexicon will try to capture words that arise in conversation or dialogue with others or that may be in circulation yet not officially seen or accepted by new media academics.

Schoolzone
http://www.schoolzone.co.uk
Schoolzone is a body appointed by DfES to carry out product evaluations for content providers listed on Curriculum Online. Schoolzone publishes a Guide to Digital Resources that lists resources evaluated to date with a brief extract of the evaluation. The last edition was sent to every school in England to help them decide how to spend their E-Learning Credits. Schoolzone publishes a newsletter to keep users up to date with its evaluation service.

TASI - Technical Advisory Service for Images
http://www.tasi.ac.uk/index.html
TASI, the Technical Advisory Service for Images, provides advice, training and news about

working with digital images. The site, geared towards supporting the FE/HE sector, contains guides and instructions about making digital image archives, managing digitisation projects and creating, delivering and using digital images. It also provides information about TASI's training events and gives examples of case studies. The site also has a digital imaging helpdesk for those needing one-to-one help with questions.

TEEM - Teachers Evaluating Educational Multimedia

http://www.teem.org.uk/

TEEM (Teachers Evaluating Educational Multimedia), formed in 1997, is a UK-based organisation that provides teachers with free access to impartial, independent, classroom-based evaluations of educational multimedia. The TEEM Web site contains evaluations of over 400 Web sites, CDs, and tools, rating them on educational details, technical details, and browser details, and giving case studies where possible. The site also contains news and press stories, an online discussion forum, and downloadable resources about digital content and educational multimedia.

TrainingZONE

http://www.trainingzone.co.uk

The TrainingZONE Web site features news, expert guides and topical articles on trends in e-learning in the training sector. The site contains a large Communities section where subscribers can communicate with each other about issues in e-learning. The site also features a reference section containing a library of e-learning documents for purchase, as well as several directories of courses, events, suppliers, trainers and consultants in e-learning. Subscribers can receive weekly newswires with updates.

Appendix B

A copy of the traditional learning material used in the experimentations

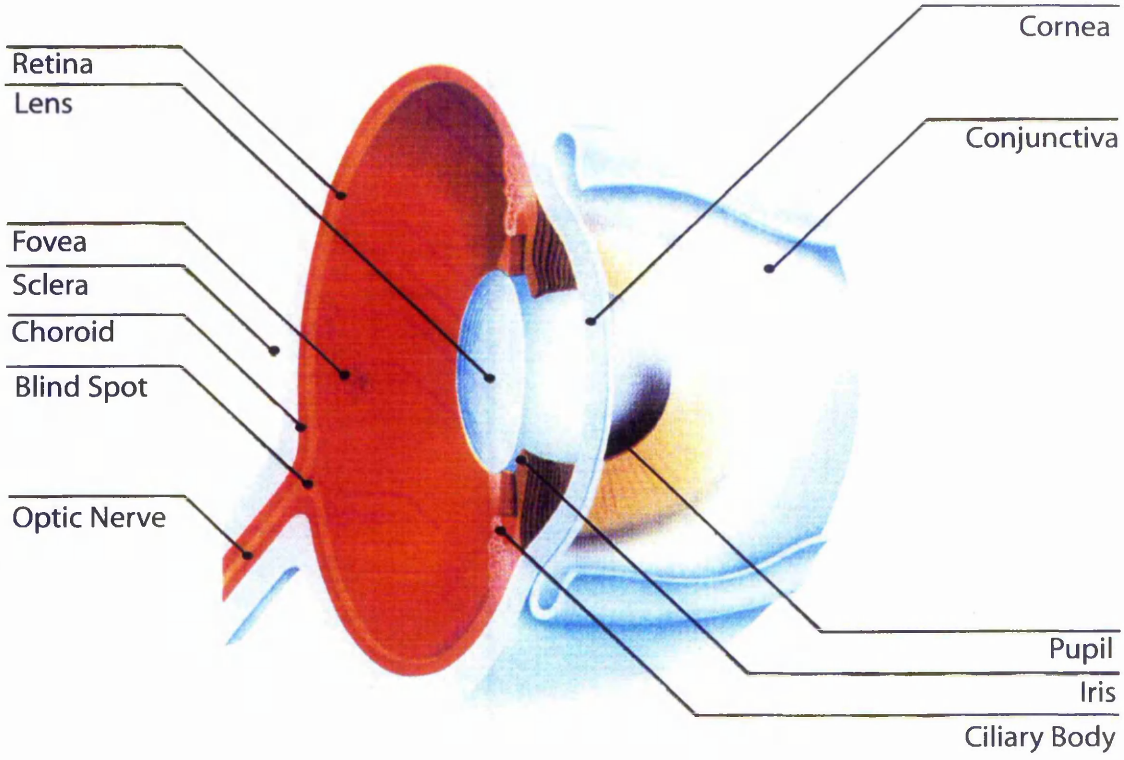
Introduction to human visual system

We humans depend on our sense of vision probably more than any of the other senses. It is our main link with the world and its wealth of imagery. Vision begins with light, the abundant rain of the sun's energy falling to earth. Light projects value, tone and shadow into nature. This light enters the eye and it then relates what it senses to the brain.

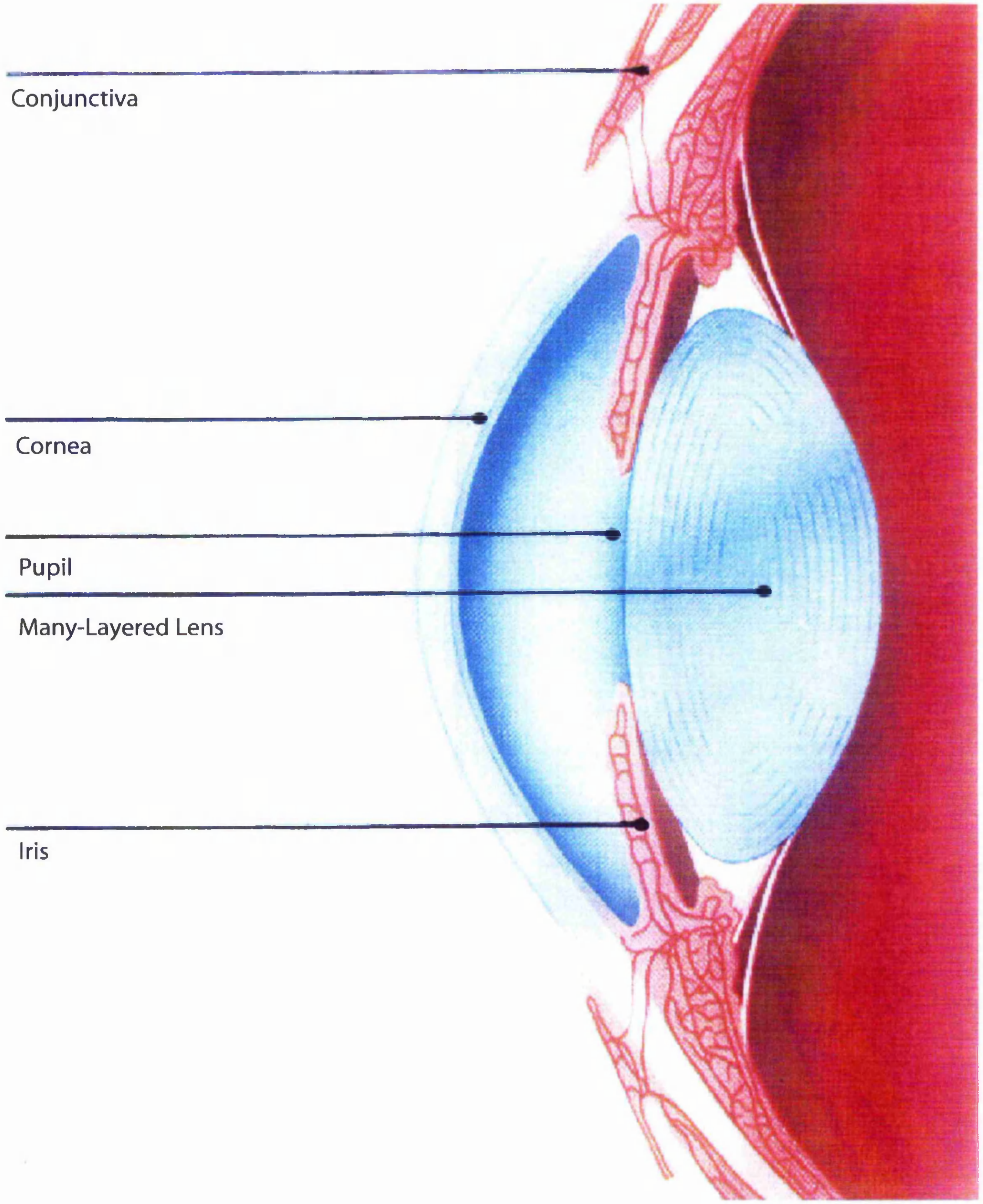
Our eyes take in an incredible amount of information, each waking second the eyes send some one billion pieces of live information to the brain. The eyes can sense about ten million gradations of light and seven million different shades of colour resulting in us possessing one of the ultimate image capturing and processing systems.

Structure of the eye

Eyes are nearly spherical, and in an adult are just under 2.5cm (1 inch) in diameter. They are protected in bony sockets in the front of the skull and can move freely, rolled in their sockets by complicated set of muscles.



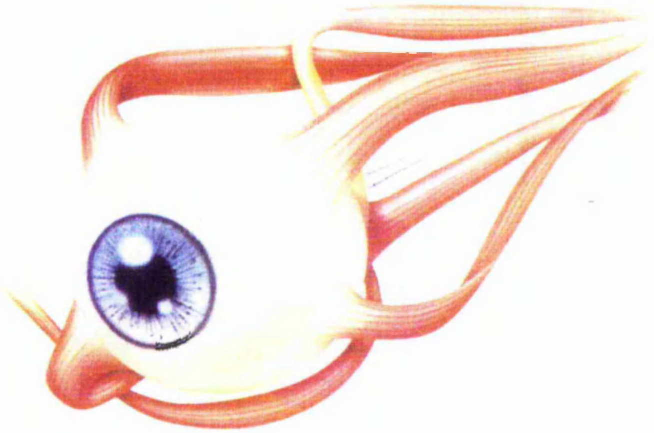
The eyeball is a soft, hollow structure, which retains its round shape because of the clear, jelly-like material called the vitreous humour which almost fills it. At the front of the eyeball this jelly is replaced with a clear watery liquid called the aqueous humour.



At the front of the eye is the clear cornea, covering the pupil and the iris. The iris regulates the amount of light that enters the eye. Light is then passed through the lens, and a picture or image is produced on the retina, the lining at the back of the eye. The whole of the eye apart from the delicate transparent cornea is covered with a tough creamy-white layer called the sclera. At the front of the eye the sclera is attached to the transparent cornea, which is visible to us as the "white" of the eye.

How the eye moves

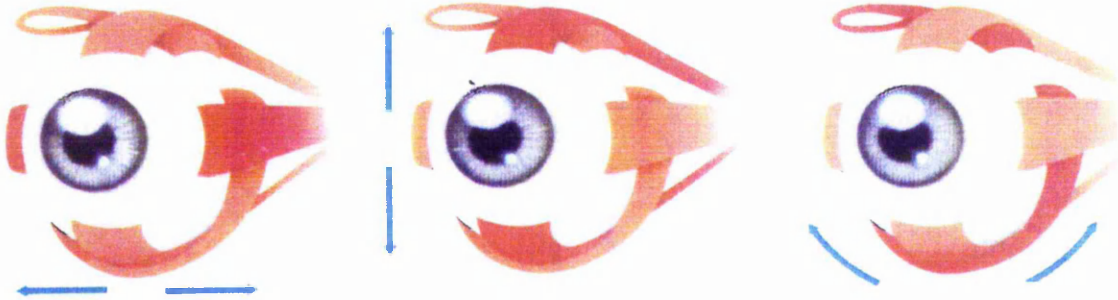
The eye fits snugly in its bony socket, but must move freely to allow us to look around without moving the head. The round eyeball rests on a layer of fat, and can rotate and move in almost any direction. Its movements are limited by the very short and thick optic nerve, which emerges from the back of the eye and passes through a hole in the bony eye socket.



Each eye is moved by six muscles which, when working together, can roll it in any direction. They are small, flat strips of muscle, attached to the sclera at one end, and to the lining of the eye socket at the other. Four of these muscles, spaced equally apart, are attached near the front of the eye. The other two wrap around the eye.

When muscles on one side of the eye pull or contract they cause the eyeball to roll toward them. In this way, the eye can be moved in any direction, 50° up, 35° down, 45° out and 50° in toward the nose. The eye rolls in toward the nose further than in any other direction to allow for convergence, where they "cross" as we look at a nearby object.

Both eyes move together, under the instruction from the brain. Turning the eyes to follow a moving object is an immensely complicated process in which the brain uses the picture it receives from the eyes to compute the speed of object. The brain issues precise instruction to two or three of the six eye muscles, telling them to contract exactly the right amount to give proper movement.

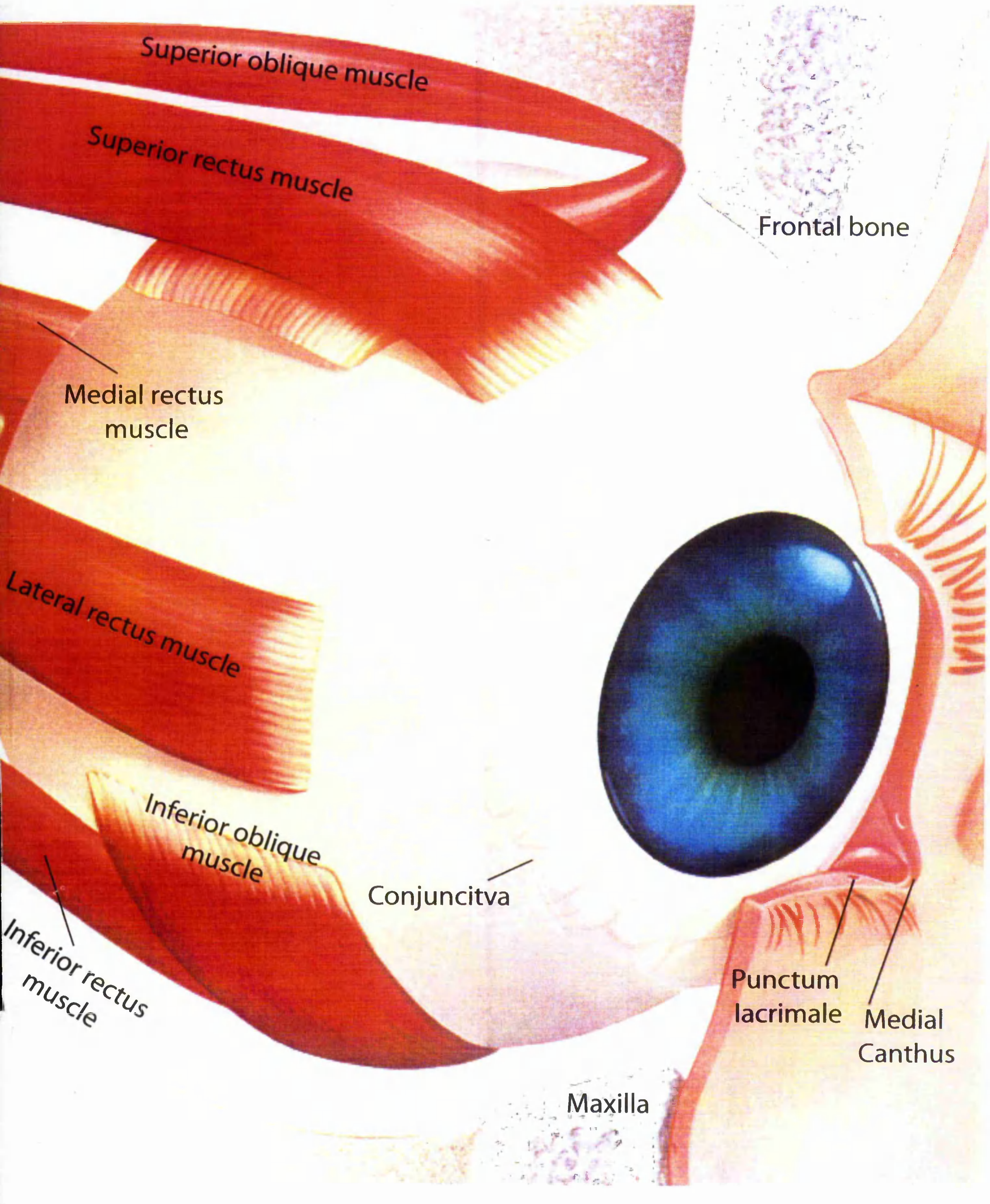


At the very front of the eye, the sclera is attached to the transparent cornea. Very thin and apparently delicate, the cornea is actually very strong, being made up of thin clear fibres similar to those in the sclera. The cornea and lens are the only parts of the living body that contain no blood vessels. This means that the cornea can be grafted on to another person's eye because there are no blood cells present to cause the rejection that often happens with other types of transplant surgery.

The most conspicuous part of the eye is the coloured iris and the pupil, which looks like a black spot at the centre. The pupil is actually a hole through the middle of the iris, and can be enlarged or narrowed as required. In strong light, the pupil closes down to a pinpoint, protecting the retina of the eye from damage. The pupil opens wide in dim light, to allow as much light as possible to enter the eye.

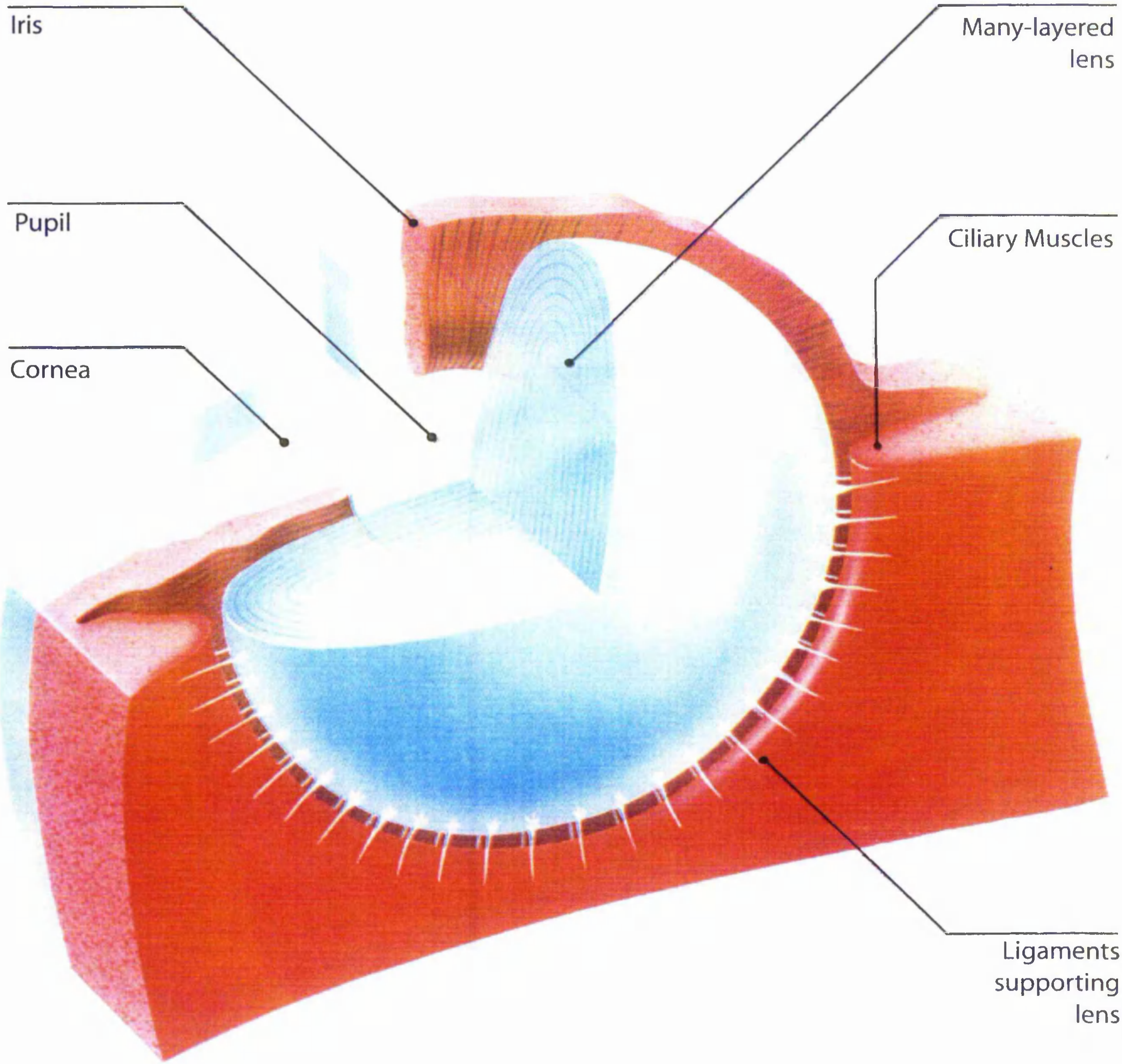
The pupil of the human eye is round, but in many animals it is a slit or a more complicated shape. The opening and closing of the pupil is completely automatic, like the "electric eye" on some types of cameras that work in a similar manner. The iris is made up of two types of muscle fibres. Some radiate out from the pupil like the arms of a starfish. As they shorten, or contract, they pull open the pupil, causing it to dilate. Other muscle fibres are arranged in rings around the pupil and they cause it to close when they contract.

The iris contracts when light intensity is high, making the pupil much smaller. A smaller part of the lens is used, however, the image falling on the retina remains the same. Instructions from the iris to open and close the pupil are sent from the brain. Acting on information it receives about the amount of light reaching the retina.

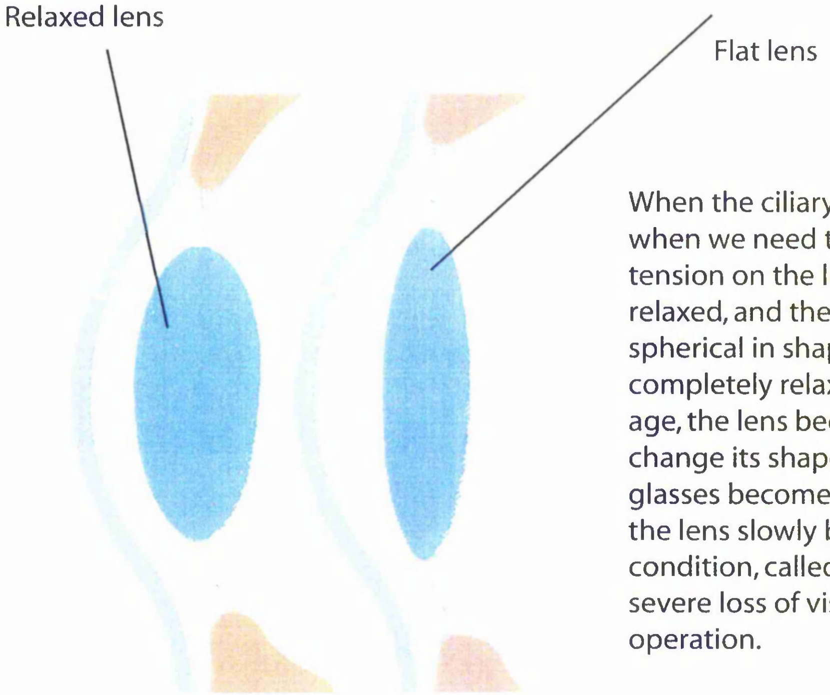

Superior oblique muscle
Superior rectus muscle
Frontal bone
Medial rectus
muscle
Lateral rectus muscle
Inferior oblique
muscle
Conjuncitva
Inferior rectus
muscle
Punctum
lacrimale
Medial
Canthus
Maxilla

The lens system

The lens of the human eye is a remarkable organ. It focuses light almost as well as a glass lens, but is highly flexible, so it can change its shape to focus at varying distances. This allows the eye to view a distant object, and then shift to look at something much closer. The lens changes its shape almost instantly to allow both objects to be seen clearly. The lens is very small, about the size of a small pea. It is slightly flattened at the front and is very clear, with a faint yellowish tinge. Unlike a glass lens, the lens of the human eye is built up from many layers of transparent cells, like the skin of an onion. Because these living cells are soft and flexible, the whole lens is rubbery and can easily change its shape.



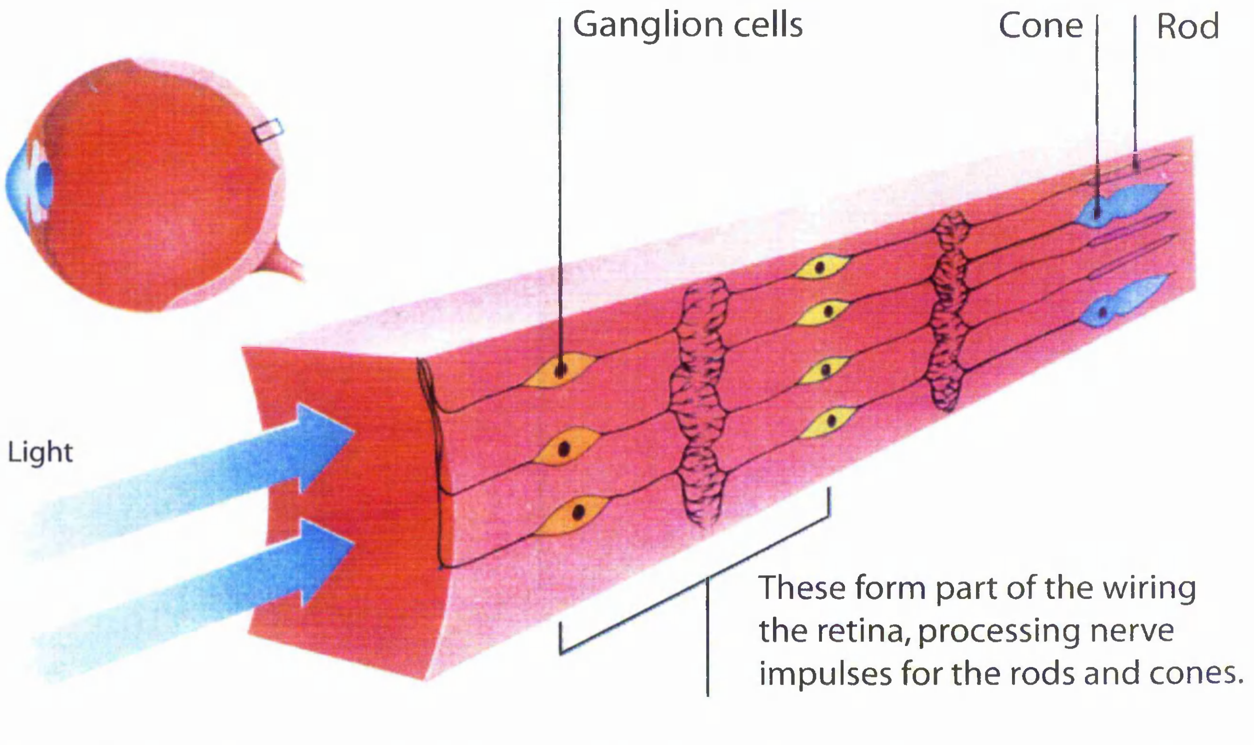
All around the outer edge of the lens are thin but very tough ligaments , which suspend the lens in position near the front of the eye, just behind the iris. The outer edges of these ligaments are joined to a ring of ciliary muscles, which are attached to the tough sclera covering the eye.



When the ciliary muscles contract, as they do when we need to look at a nearby object, the tension on the ligament holding the lens is relaxed, and the lens bulges and becomes nearly spherical in shape. When the ciliary muscles are completely relaxed, the lens is much flatter. As we age, the lens becomes more rigid and cannot change its shape so easily. This can mean that glasses become necessary for reading. Sometimes the lens slowly becomes cloudy and this condition, called cataract, may eventually lead to severe loss of vision. It can be corrected by an eye operation.

The retina

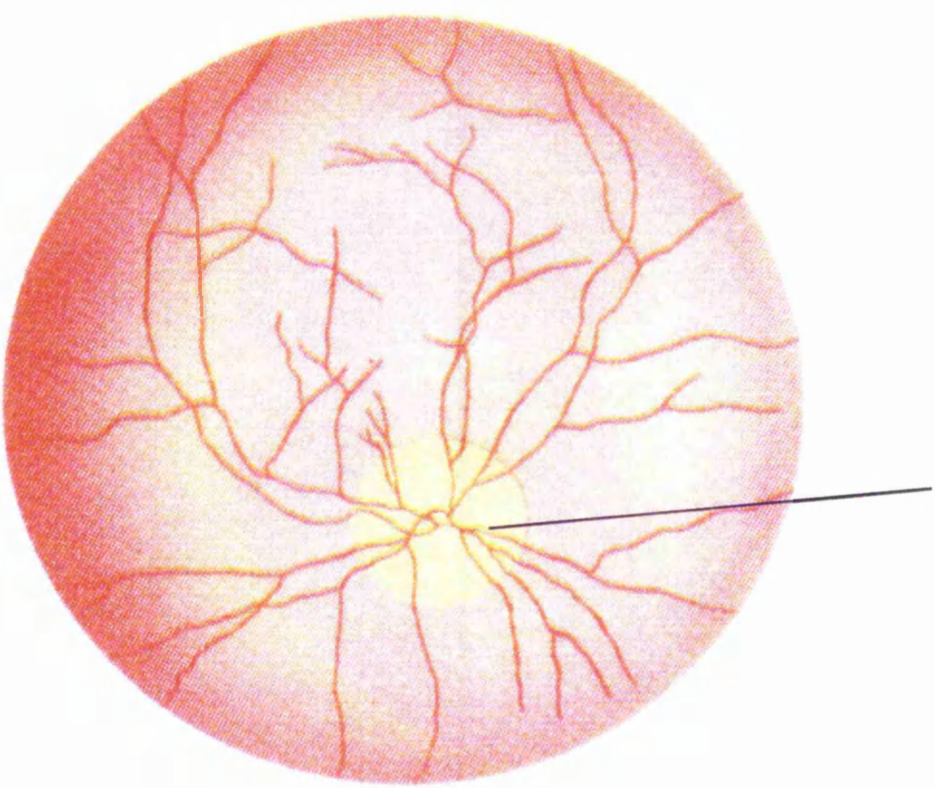
The retina is a cup-shaped inner lining of the back of the eye. Light entering the eye is focused by the lens to produce an image, upside down and back to front, on the retina. The retina can detect this image and turn it into a series of coded electrical signals, which are passed along nerves to the brain. The retina is made up of several layers of cells, giving it the ability to process and alter the images falling on its surface before they are passed on to the brain. These layers contain huge numbers of specials cells called rods and cones. These cells are sensitive to light and are called photoreceptors. The retina of each eye contains about 125 million rods and 7 million cones, packed tightly together. Their position in the retina is unusual, because they are buried quite deeply, with their light-sensitive structures facing the back of the eyeball.



Over the rods and cones is a complicated arrangement of nerve fibres, or neurons, called ganglion cells, each of which is in contact with many other rods and cones. These neurons connect with other nerve fibres which carry signals out of the eye to the brain.

There are only about 800,000 of these nerve fibres leading from the eye, as signals from the rods and cones are simplified and "cleaned up" by the nerve fibres inside the retina. Light reaching the sensitive rods and cones has to pass through the mass of nerve fibre, and through the body of the rods and cones themselves before it reaches the sensitive parts which cause an electrical signal to be produced. Rods and some cones are spread over the whole retina, but it is mostly cones that are grouped in a central part called the **fovea**. This is the most sensitive part of the retina, where an image is" seen" most clearly.

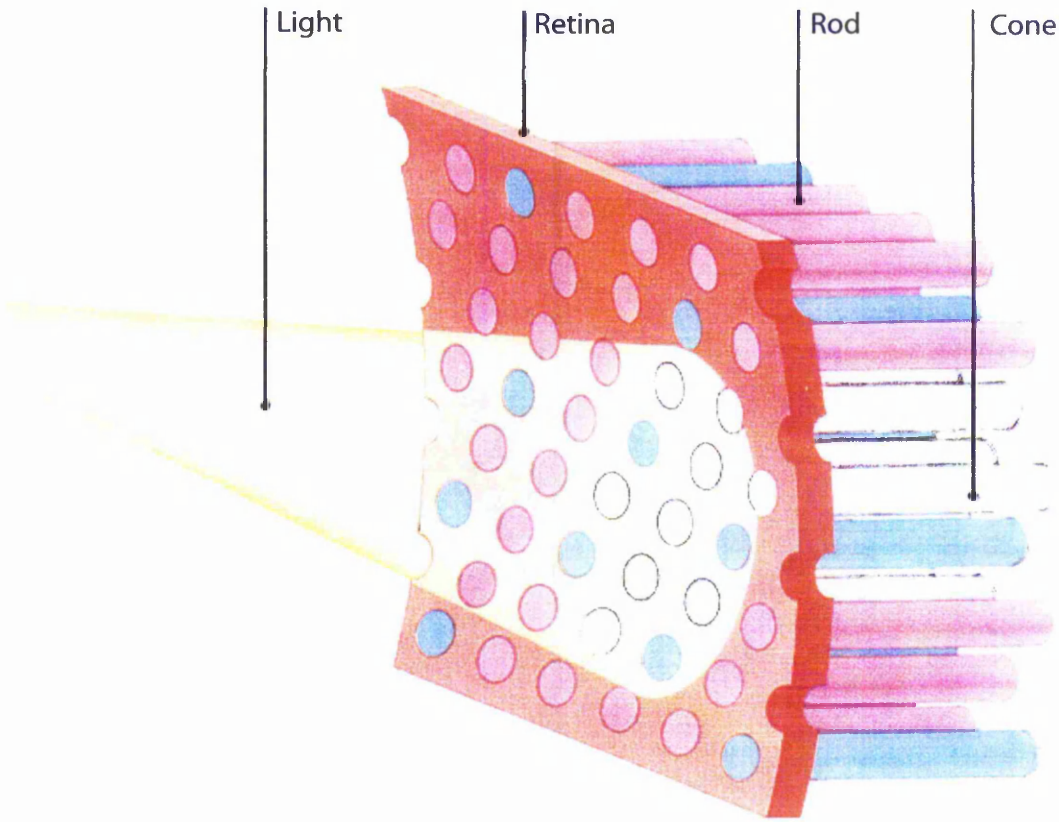
The retina is covered with fine, branching blood vessels. They all arise from the one small area the retina which has no rods or cones and where the nerve fibres leave the retina to pass into the **optic nerve**. There is a small dimple in the surface of the retina at this point and is known as the **blind spot.**



To illustrate the blind spot close your left eye and stare at the round spot (on the next page) on the left. Move the page gradually closer to your eye , and when it is about 20cm away the cross will suddenly vanish. The image of the cross is now falling on the blind spot on your retina.

Rods and cones

Rods and cones are tiny cells from each of which runs a fine thread leading to a nerve fibre. Rods are long, thin cells which contain a substance called visual purple, or **rhodopsin.** When visual purple is exposed to light, a chemical change takes place, and the colour in the rods is bleached out. This reaction causes an electrical signal to be produced and passed on to the connecting nerve fibre.



Rods are very sensitive to light and are important for night vision. They respond to ordinary white light, so everything "seen" with the rods is in shades of grey. In very bright light, visual purple becomes inactive. It slowly regains it's normal purple colouring in darkness, and this may take thirty minutes or more. You can see the results by going from a brightly lit room into near darkness: it can take anything up to an hour for the eye to become accustomed to the poor light.

Cone cells are responsible for colour vision. They contain one of three different chemicals which are also bleached by light. They respond to either red, yellow-green, or blue-violet light. All other colours are "seen" as a combination of these. Cone cells are stimulated only by bright light, and the also allow us to make out fine detail.

lln the sensitive fovea, where an image is seen most clearly, cones are packed tightly together. Here each nerve fibre is in contact with only one or two cones. Elsewhere in the retina, where most of the rods are positioned, there are about 300 rods connected to each nerve fibre. This means that the brain receives much more detailed information from the cones in the fovea than it does from the rods in the rest of the retina.

Appendix C

A copy of the electronic learning material used in the experimentations (see back cover for sleeve)

Appendix D

A copy of the pre-test material used in the experimentations

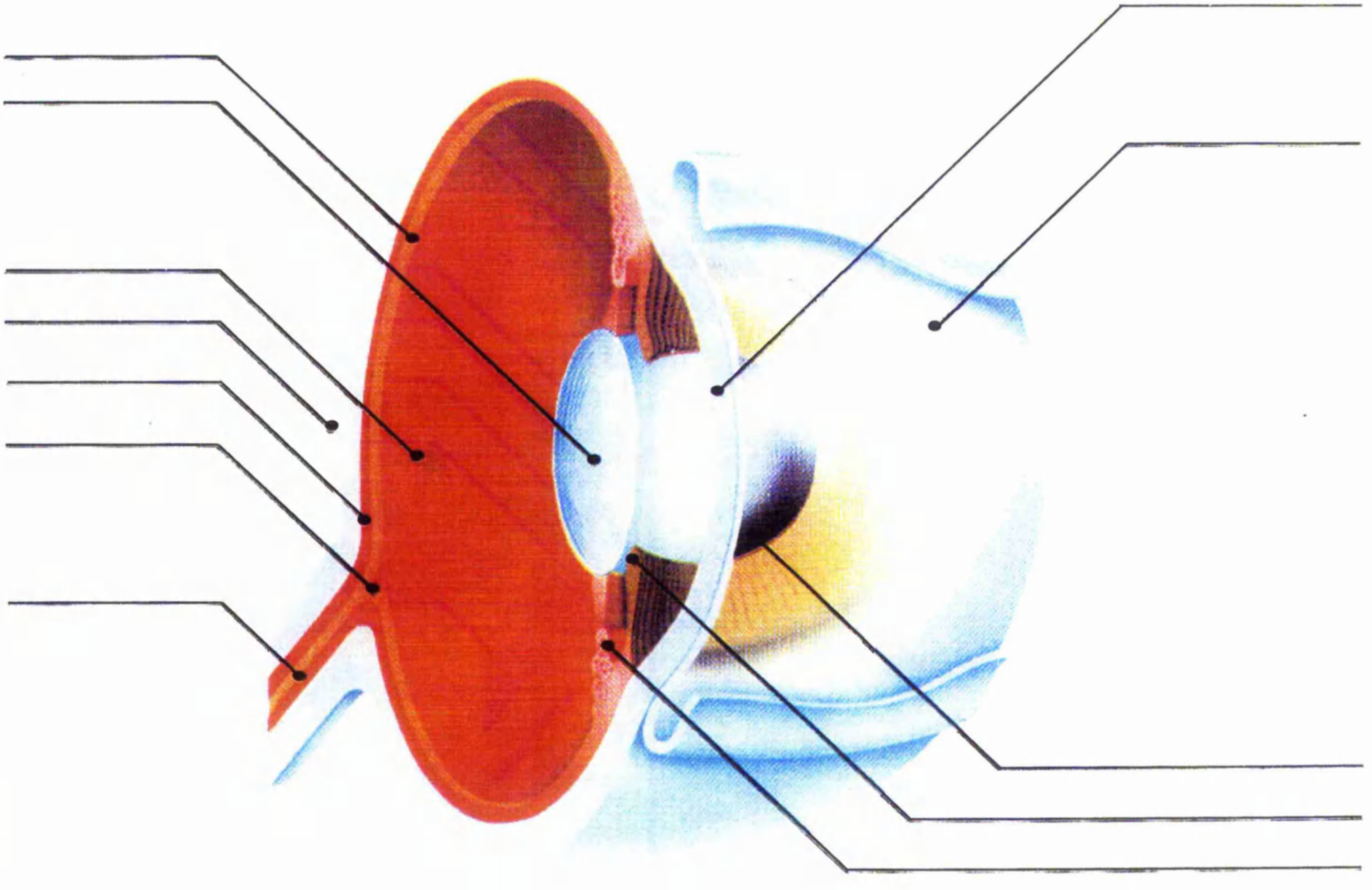
This exercise is part of a research experiment, this is not an assessment!

Your name will only be used to match up your pre/post test results and data will be represented statistically.

Name of participant ....

Pre - Test Evaluation

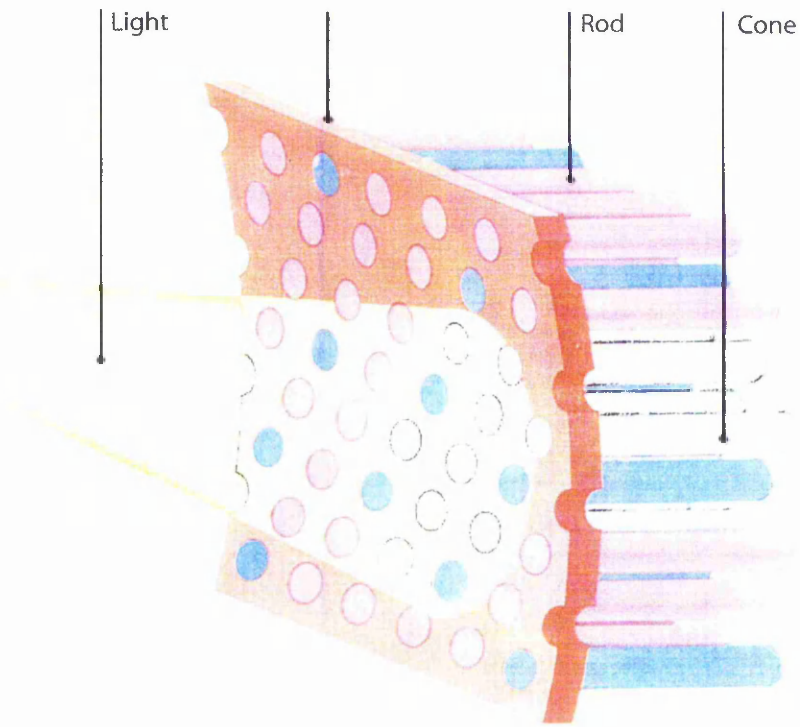
The diagram below is an illustration of the inside and outside of a human eye. Please label any parts of the eye that you are relatively sure are correct, please do not just guess at random:



Focus on the circle below with your right eye while closing your left eye. Move the page gradually closer to your eye , when it is about 30cm away the cross will suddenly vanish.

Can you briefly explain why this happens, again please do not guess, leave blank if unsure:

The diagram below illustrates a specific part of the human eye, do you know what it is:



What is the primary cause of shortsightedness?

Tick one of the following that describes your knowledge of the human visual system:

No to little knowledge ☐ Little to basic ☐ Basic to intermediate ☐ Intermediate to advanced ☐ Advanced ☐

Have you previously studied or have been exposed to learning material associated with the human visual system ? i.e. Biological lessons covering this topic, documentaries on human anatomy, etc.

Yes ☐ No ☐

If yes please give details of curriculum (GCSE Science, A/S Level Biology, or similar) and duration of study:

....

....

Have you previously had any experience in using distance learning material in a electronic format? (This may have been on a learning package on a personal computer, a web based tutorial or simulation program).

Never ☐ Once or twice ☐ Twice or more ☐ More than five times ☐

Could you give details of the type of distance learning material and the subject matter covered.

....

....

~~Could you please give details of you UCAS entry points or equivalent qualifications and grades.~~

....

....

Please indicate your age and sex:

18 - 25 ☐ 25 + ☐ Male ☐ Female ☐

Appendix E

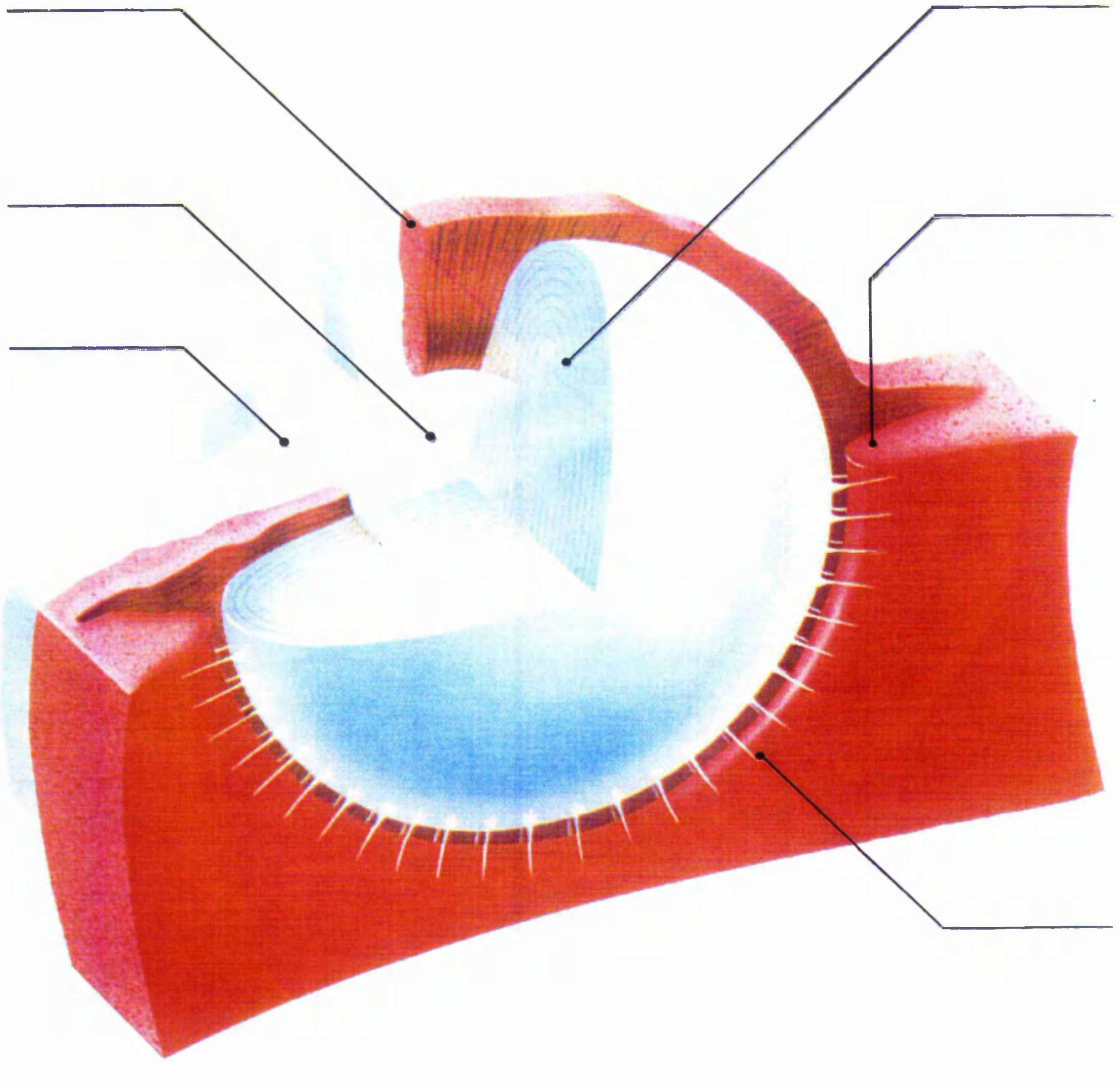
Post-test evaluation material used in the experimentations

This exercise is part of a research experiment, this is not an assessment! Your name will only be used to match up your pre/post test results.

Name of participant ....

<u>Post - Test Evaluation</u>

The diagram below is an illustration of the lens system of a human eye. Please label any parts of the eye that you are relatively sure are correct, please do not just guess at random parts.



The pupil of the eye opens and closes, why does this occur and how is this achieved:

Occurs due to: ....

This is achieved by: ....

....

The lens in the human eye serves an important role, what is this role and how does it achieved this:

The role is to: ....

This is achieved by: ....

....

In many instances lenses do not stretch and relax as desired; what is the result of this on the light rays entering the eye and how does this impact on vision:

Result: ....

Impact on vision: ....

Light is received by a specific part of the eye that contains millions of cells, name this part of the eye, and the three main types of cells that make up this part of the eye:

The part of the eye: ....

The name of the 3 main types of cells:

....

Can you name the area relating to the above question with the greatest concentration of photoreceptive cells:

....

Can you name the area relating to the previous question where no photoreceptive cells are found:

....

What common action is required once the lens in the eye becomes ridged?

....

How big is a human eye and what shape is it usually?

Size = ...   Shape = ...

The eye uses muscles to move, how many muscles allow the eye to do this and by how much does the eye move in each direction:

Number of muscles = ...

Degree of movement upwards ......   Degree of movement downwards ....

Degree of movement in towards nose ......

Degree of movement out away from the nose......

Can you name the following muscles that move the eye:

Muscle that moves eye in towards the nose ....

Muscle that moves eye outwards ....

Muscle that moves eye upwards ....

Tick one of the following that describes your knowledge of the human visual system:

No to little knowledge ☐ Little to basic ☐ Basic to intermediate ☐ Intermediate to advanced ☐ Advanced ☐

Appendix F

Feedback forms used in the experimentations and post test evaluation

<u>An introduction to the human visual system</u>

<u>Feedback form</u>

Please complete the short questionnaire regarding the learning package that you just undertook.

1. Have you previously used any electronic learning packages?

   Yes ☐ No ☐ Not Sure ☐

   i) If so, how many different packages? ....

   ii) What were the subject matters regarding ? ....

   ....

   iii) Where did you come into contact with them ? ....

   ....

   iv) Did you enjoy using them ? Yes ☐ No ☐ Not Sure ☐

   v) Summarising, could you indicate (with a mark) how effective (degree of educational value) you thought they were ?

Ineffective	Little educational value	Uncertain of effectiveness	Highly educational	Extremely effective

2. Did you find learning from this electronic learning package to be more or less stimulating then using traditional means of learning ?

   Less ☐ Same ☐ More ☐

   i. Could you indicate (with a mark anywhere on the horizontal line) how effective (degree of educational value) you thought this electronic learning package was ?

Ineffective	Little educational value	Uncertain of effectiveness	Highly educational	Extremely effective

3. Excluding computer hardware system issues experienced, could you indicate to what degree did this electronic learning package maintain your interest?

....

Ineffective	Little interest maintained	Some interest	Interest generally maintained	Interesting throughout

4. Could you indicate to what degree your motivation to learn was affected by the material being presented:

....

Ineffective	Little motivation	Some motivation	Generally motivating	Highly motivating	Extremely motivating

5. Could expand on answers to the above: (what you found most effective, what attracts you to this form of learning, what advantages for you are there using this form of learning, etc..)

....
....
....
....
....
....

6. How could this electronic learning package be improved ?

....
....
....
....

Thank you for helping with this research

Appendix G

Scripts used for the recording of the narration included within the ELM package

Scripts

Electronic version

Introduction

a) We humans depend on our sense of vision probably more than any of the other senses. It is our main link with the world and its wealth of imagery. Vision begins with light, the abundant rain of the sun's energy falling to earth. Light project value, tone and shadow into nature. This light enters the eye and it then relates what it senses to the brain.

b) Our eyes take in an incredible amount of information, each waking second the eyes send some one billion pieces of live information to the brain. The eyes can sense about ten million gradations of light and seven million different shades of colour resulting in us possessing one of the ultimate image capturing and processing systems.

Main menu

Exterior

Outer parts

a) Eyes are nearly spherical, and in an adult are just under 2.5cm (1 inch) in diameter.

b) The eyeball is a soft, hollow structure, which retains its round shape because of the clear, jelly-like material called the **vitreous humour** which almost fills it. At the front of the eyeball this jelly is replaced with a clear watery liquid called the **aqueous humour**.

c) The round eyeball rests on a layer of fat, and can rotate and move in almost any direction. Its movements are limited by the very short and thick optic nerve, which emerges from the back of the eye and passes through a hole in the bony eye socket.

d) At the front of the eye is the clear **cornea** covering the pupil and the **iris**. The whole of the eye apart from the delicate transparent cornea is covered with a tough creamy-white layer called the **sclera.**

c) At the front of the eye the sclera is attached to the transparent cornea and is visible to us as the "white" of the eye.

d) The pupil of the human eye is round, but in many animals it is a slit or a more complicated shape. The iris is made up of two types of muscle fibres. Some radiate out from the pupil like the arms of a starfish. As they shorten, or contract, they pull open the pupil, causing it to dilate.

Pupil

a) The most conspicuous part of the eye is the coloured iris and the pupil, which looks like a black spot at the centre. The pupil; is actually a hole through the middle of the iris, and can be enlarged or narrowed as required. The **iris** regulates the amount of light that enters the eye.

b) In strong light, the pupil closes down to a pinpoint, protecting the retina of the eye from damage. The pupil opens wide in dim light, to allow as much light as possible to enter the eye.

c) The opening and closing of the pupil is completely automatic, like the "electric eye" on some types of cameras that work in a similar manner.

d) Other muscle fibres are arranged in rings around the pupil and they cause it to close when they contract.

Muscles

a) The muscles are small, flat strips of muscle, attached to the sclera at one end, and to the lining of the eye socket at the other.

b) The superior rectus and inferior rectus allow the eye to be moved upwards and downwards respectively.

c) Four of these muscles, spaced equally apart, are attached near the front of the eye. The other two wrap around the eye.

d) When muscles on one side of the eye pull or contract they cause the eyeball to roll toward them. In this way, the eye can be moved in the desired direction.

e) 50 degrees up

f) 35 degrees down

g) The medial rectus and lateral rectus allow the eye to move 50 degress in towards the nose and 45 degrees outwards away from the nose.

h) Each eye is moved by six muscles the other two being the superior oblique and inferior oblique. When all six muscles are working together, they can roll the eye in any direction.

i) The eye rolls in toward the nose further than in any other direction to allow for **convergence**. This is where the eyes "cross" as we look at a nearby object.

Interior

Lens system

a) At the very front of the eye, the sclera is attached to the transparent cornea. Very thin and apparently delicate, the cornea is actually very strong, being made up of thin clear fibres similar to those in the sclera.

b) The lens of the human eye is a remarkable organ. It focuses light almost as well as a glass lens, but is highly flexible, so it can change its shape to focus at varying distances.

c) The lens is very small, about the size of a small pea. It is slightly flattened at the front and is very clear, with a faint yellowish tinge. This type of lens is called a convex lens and in the eye is rounded on the front and back.

d) Unlike a glass lens, the lens of the human eye is built up from many layers of transparent cells, like the skin of an onion. Because these living cells are soft and flexible, the whole lens is rubbery and can easily change its shape.

Ligaments cutaway

a) All around the outer edge of the lens is a thin but very tough ligaments , which suspends the lens in position near the front of the eye, just behind the iris.

b) The outer edge of this ligament is joined to a ring of ciliary muscles, which are attached to the tough sclera covering the eye.

Lens bending light

a) To understand how a picture or image is formed at the back of the eye, it is necessary to know how light rays are altered while entering the eye.

b) Rays of light enter the front of the eye refracting through the transparent cornea and then passing through the lens. In a lens which is thicker in the centre then at the edges, like the lens in the eye, the light rays passing through it are bent toward the centre of the lens.

c) When the ciliary muscles contract, as they do when we need to look at a nearby object, the tension on the ligament holding the lens is relaxed, and the lens bulges and becomes nearly spherical in shape.

d) When the ciliary muscles are completely relaxed, the lens is much flatter. As we age, the lens becomes more rigid and cannot change its shape so easily. This can mean that glasses become necessary for reading. Sometimes the lens slowly becomes cloudy and this condition, called cataract, may eventually lead to severe loss of vision. It can be corrected by an eye operation.

Parrallel light rays

a) The highly flexible nature of the lens allows the eye to view a close up objects, and then shift to look at something much further away. The angle at which the light rays from these objects enter the eye differs with the distant rays being almost parallel.

b) The light rays are passed through the **lens**, and a picture or image is produced on the retina, the lining at the back of the eye.

c) The lens changes its shape almost instantly to allow the light rays to be brought to a sharp focus on the retina.

Retina

a) Passing through into the vitreous humor and delving deeper into the eye, into its main chamber. Here the retina lies in the cup shaped inner lining of the back of the eye.

b) The retina is covered with fine, branching blood vessels they all arise from the one small area the retina which has no rods or cones and where the nerve fibres leave the retina to pass into the **optic nerve**. There is a small dimple in the surface of the retina at this point and is known as the **blind spot**.

c) Light entering the eye is focused by the lens to produce an image, upside down and back to front, on the retina. The retina can detect this image and turn it into a series of coded electrical signals, which are passed along nerves to the brain.

d) The retina is made up of several layers of cells, giving it the ability to process and alter the images falling on its surface before they are passed on to the brain. These layers contain huge numbers of specials cells called **rods** and **cones**. These cells are sensitive to light and are called photoreceptors.

e) Rods and cones are tiny cells from each of which runs a fine thread leading to a nerve fibre.

f) Rods are very sensitive to light and are important for night vision. They respond to ordinary white light, so everything "seen" with the rods is in shades of grey. In very bright light, visual purple colouring in darkness, and this may take thirty minutes or more. You can see the results by going from a brightly lit room into near darkness: it can take anything up to an hour for the eye to become accustomed to the poor light.

g) Cone cells are responsible for colour vision. They contain one of three different chemicals which are also bleached by light. They respond to either red, yellow-green, or blue-violet light. All other colours are "seen" as a combination of these.

h) In the sensitive fovea, where an image is seen most clearly, cones are packed tightly together. Here each nerve fibre is in contact with only one or two cones. Elsewhere in the retina, where most of the rods are positioned, there are about 300 rods connected to each nerve fibre. This means that the brain receives much more detailed information from the cones in the fovea than it does from the rods in the rest of the retina.

i) Sentence on the macula please ???

j) The cone cells are stimulated only by bright light, and allow us to make out fine detail.

Retina in detail

a) Rods are long, thin cells which contain a substance called visual purple, or **rhodopsin**. When visual purple is exposed to light, a chemical change takes place, and the colour in the rods is bleached out. This reaction causes an electrical signal to be produced and passed on to the connecting nerve fibre

b) The retina of each eye contains about 125 million rods and 7 million cones, packed tightly together. Their position in the retina is unusual, because they are buried quite deeply, with their light-sensitive structures facing the back of the eyeball.

c) Over the rods and cones is a complicated arrangement of nerve fibres, or neurons, called ganglion cells, each of which is in contact with many other rods and cones. These neurons connect with other nerve fibres which carry signals out of the eye to the brain.

d) There are only about 800,000 of these nerve fibres leading from the eye, as signals from the rods and cones are simplified and "cleaned up" by the nerve fibres inside the retina.

e) Light reaching the sensitive rods and cones has to pass through the mass of nerve fibre, and though the body of the rods and cones themselves before it reaches the sensitive parts which cause an electrical signal to be produced.

f) The electrical signal is passed then back through the mass of nerve fibres, firstly via the bipolar cells, then onto the ganglion cells and finally out to the brain along the optic nerves.

Cutaways

a) The iris contracts when light intensity is high, making the pupil much smaller. A smaller part of the lens is used, however, the image falling on the retina remains the same. Instructions from the iris to open and close the pupil are sent from the brain. Acting on information it receives about the amount of light reaching the retina.

b) The eyes are protected in bony sockets in the front of the skull and can move freely, rolled in their sockets by complicated set of muscles.

c) The eye fits snugly in its bony socket, but must move freely to allow us to look around without moving the head

d) The cornea and lens are the only parts of the living body that contain no blood vessels. This means that the cornea can be grafted on to another person's eye because there are no blood cells present to cause the rejection that often happens with other types of transplant surgery.

e) Both eyes move together, under the instruction from the brain. Turning the eyes to follow a moving object is an immensely complicated process in which the brain uses the picture it receives from the eyes to compute the speed of object.

f) The brain issues precise instruction to two or three of the six eye muscles, telling them to contract exactly the right amount to give proper movement.

Appendix H

Full results – complete tables

Full results Phase 1 : - TLM

Student	Pre Test Score / 36	Pre Test Score / %	Post Test Score / 56	Post Test Score %	Percentage Change	Ucas Tariff points	Reason for anomaly
AE211590	14	39%	36	64%	**25.4%**	210	
CA203950	0	0%	28	50%	**50.0%**	60	
CC213850	2	6%	33	59%	**53.4%**	380	
CC215160	10	28%	34	61%	**32.9%**	360	
FC241810	4	11%	18	32%	**21.0%**	220	
FC243320	6	17%	26	46%	**29.8%**	290	
GB118210	10	28%	18	32%	**4.4%**		
GB222880	6	17%	24	43%	**26.2%**	220	
HC206620	0	0%	26	46%	**46.4%**	140	
HC206650	18	50%	43	77%	**26.8%**	260	
N0015057	12	33%	30	54%	**20.2%**		
N0016611	24	67%	26	46%	**-20.2%**	280	Prior knowledge V. Good
N0016920	22	61%	25	45%	**-16.5%**	320	Prior knowledge V. Good
N0016948	2	6%	31	55%	**49.8%**	240	
N0017096	2	6%	27	48%	**42.7%**	350	
N0017613	6	17%	37	66%	**49.4%**	320	
N0019812	24	67%	40	71%	**4.8%**	220	
N0021047	10	28%	32	57%	**29.4%**	310	
N0021203	22	61%	34	61%	**-0.4%**	210	Prior knowledge V. Good
N0021362	2	6%	35	63%	**56.9%**	240	
N0021676	20	56%	46	82%	**26.6%**	480	
N0024213	8	22%	30	54%	**31.3%**	320	
N0024736	2	6%	28	50%	**44.4%**	350	
N0024755	2	6%	26	46%	**40.9%**	260	
N0026893	0	0%	28	50%	**50.0%**	240	
N0027975	4	11%	16	29%	**17.5%**		
N0028344	26	72%	32	57%	**-15.1%**	300	Prior knowledge V. Good
N0028354	18	50%	33	59%	**8.9%**	280	
N0029563	8	22%	27	48%	**26.0%**	220	
N0029968	2	6%	23	41%	**35.5%**	250	
N0030152	2	6%	27	48%	**42.7%**	250	
N0032529	0	0%	18	32%	**32.1%**	10	
N0033045	0	0%	38	68%	**67.9%**	140	
N0033408	0	0%	14	25%	**25.0%**	220	
N0034554	0	0%	18	32%	**32.1%**	120	
N0035126	2	6%	14	25%	**19.4%**	10	
N0035252	14	39%	46	82%	**43.3%**	200	
N0035430	18	50%	51	91%	**41.1%**	350	
N0035989	4	11%	17	30%	**19.2%**	200	
N0036603	17	47%	20	36%	**-11.5%**	220	
N0037578	24	67%	44	79%	**11.9%**	280	
N0037582	6	17%	22	39%	**22.6%**	200	
N0037898	2	6%	17	30%	**24.8%**	220	
N0037902	6	17%	30	54%	**36.9%**	180	
N0038145	2	6%	35	63%	**56.9%**	160	
N0038526	8	22%	33	59%	**36.7%**		
N0038528	10	28%	38	68%	**40.1%**		
N0039158	4	11%	16	29%	**17.5%**	200	
N0039275	3	8%	23	41%	**32.7%**	140	
N0039309	0	0%	9	16%	**16.1%**	30	
N0039865	10	28%	27	48%	**20.4%**	280	
N0040445	10	28%	28	50%	**22.2%**	150	
N0040765	0	0%	16	29%	**28.6%**	150	
N0041242	10	28%	20	36%	**7.9%**	240	
N0041505	4	11%	26	46%	**35.3%**		

Full results Phase 1 : - TLM Con't...

Student	Pre Test Score / 36	Pre Test Score / %	Post Test Score / 56	Post Test Score %	Percentage Change	Ucas Tariff points	Reason for anomaly
N0043313	0	0%	6	11%	**10.7%**		
N0044486	9	25%	31	55%	**30.4%**	140	
N0048053	10	28%	20	36%	**7.9%**	40	
N0048356	2	6%	19	34%	**28.4%**		
N0049989	7	19%	18	32%	**12.7%**		
N0050419	6	17%	20	36%	**19.0%**	160	
N0050436	10	28%	24	43%	**15.1%**		
N0050564	0	0%	16	29%	**28.6%**		
N0051208	8	22%	26	46%	**24.2%**	220	
N0051215	22	61%	53	95%	**33.5%**	200	
N0052413	2	6%	16	29%	**23.0%**		
N0052420	25	69%	32	57%	**-12.3%**		Prior knowledge V. Good
N0052542	0	0%	7	13%	**12.5%**		
N0052851	10	28%	27	48%	**20.4%**		
N0053545	12	33%	27	48%	**14.9%**		
N0054353	0	0%	37	66%	**66.1%**		
Mean Results:	**8.0**	**22.10%**	**27.0**	**48.24%**	**26.13%**	**223.0**	
Stdev:	**7.6**		**9.8**			**94.4**	
Variance:	**58**		**96**			**8908**	

Full results Phase 1 : - ELM

Student	Pre Test Score / 36	Pre Test Score / %	Post Test Score / 56	Post Test Score %	Percentage Increase	Ucas Tariff points	Reason for anomaly
CA204650	16	44%	29	52%	**7.3%**	200	
CC213330	14	39%	34	61%	**21.8%**	340	
CC215390	12	33%	49	88%	**54.2%**	130	
CC215620	20	56%	18	32%	**-23.4%**	80	Prior knowledge V. Good
GB224600	20	56%	38	68%	**12.3%**	280	
N0014281	6	17%	37	66%	**49.4%**		
N0014284	2	6%	33	59%	**53.4%**		
N0014289	2	6%	30	54%	**48.0%**		
N0016199	6	17%	28	50%	**33.3%**	380	
N0018086	10	28%	26	46%	**18.7%**	400	
N0018202	0	0%	28	50%	**50.0%**	330	
N0032183	12	33%	46	82%	**48.8%**	200	
N0032367	8	22%	40	71%	**49.2%**	410	
N0032576	4	11%	42	75%	**63.9%**	410	
N0032862	4	11%	21	38%	**26.4%**	280	
N0034505	14	39%	22	39%	**0.4%**	220	
N0034673	4	11%	42	75%	**63.9%**	230	
N0037280	10	28%	50	89%	**61.5%**	240	
N0039004	15	42%	44	79%	**36.9%**	340	
N0039185	4	11%	19	34%	**22.8%**	200	
N0044930	10	28%	42	75%	**47.2%**	240	
N0045480	12	33%	38	68%	**34.5%**		
N0051198	6	17%	24	43%	**26.2%**	60	
N0051581	26	72%	34	61%	**-11.5%**		Prior knowledge V. Good
N0051839	4	11%	14	25%	**13.9%**		
Mean Results:	**9.6**	**26.78%**	**33.1**	**59.14%**	**32.4%**	**261.6**	
Stdev:	**6.4**		**9.9**			**102.8**	
Variance:	**42**		**102**			**11158**	

Full results phase 2 : - Text and Graphics Results

	Student number	Pre test score		Self Index pre knowledge	UCAS Traiff points	Previous knowledge of HVS		Age	Post test score		Self Index of post knowledge	Percentage change	Additional Comments
		Score	%			HVS Specific	Description of study		Score	%			
1	N0024993	6.0	16.7%	1		1	GCSE	18 - 25	34.0	65.4%	2	48.7%	
2	N0025221	20.0	55.6%	3	400	1	Biology 4 years	18 - 25	32.0	61.5%	4	6.0%	
3	N0042074	9.0	25.0%	2	290	1	GCSE Science	18 - 25	25.0	48.1%	2	23.1%	
4	N0044436	6.0	16.7%	2		1	GCSE	18 - 25	15.0	28.8%	3	12.2%	
5	N0056593	0.0	0.0%	1	260	0	N/A	18 - 25	23.0	44.2%	2	44.2%	
6	N0060408	18.0	50.0%	3	260	1	A level Biology	18 - 25	41.0	78.8%	3	28.8%	
7	N0063056	20.0	55.6%	2	250	1	GCSE Science	18 - 25	37.0	71.2%	2	15.6%	
8	N0063223	6.0	16.7%	2	270	1	GCSE Science	18 - 25	33.0	63.5%	3	46.8%	
9	N0063695	12.0	33.3%	2	240	1	GCSE	18 - 25	22.0	42.3%	2	9.0%	
10	N0067378			1		1	GCSE Science	18 - 25			2		Anomaly
11	N0071642			2		1	AS Biology	18 - 25			2		Anomaly
12	N0073163	8.0	22.2%	1	240	1	Single Award GCSE Science	18 - 25	13.0	25.0%	3	2.8%	
13	N0076282	0.0	0.0%	N/A		1	GCSE Science	18 - 25	30.0	57.7%	2	57.7%	
14	N0078286	0.0	0.0%	2	220	1	GCSE	18 - 25	16.0	30.8%	3	30.8%	
15	N0078665	12.0	33.3%	2	200	1	2xGCSE, TV documentaries	18 - 25	38.0	73.1%	3	39.7%	
16	N0078807	2.0	5.6%	1	220	0	N/A	18 - 25	23.0	44.2%	2	38.7%	
17	N0078994	22.0	61.1%	2		1	GCSE	18 - 25	36.0	69.2%	3	8.1%	
18	N0081560	8.0	22.2%	2		1	GCSE Science & GNVQ	18 - 25	40.0	76.9%	3	54.7%	
19	N0081569	2.0	5.6%	1	320	1	GCSE Science	18 - 25	20.0	38.5%	2	32.9%	
	Means:	**7.95**	**24.7%**	**1.053**	**264.2**	**0.895**			**25.16**	**54.07%**	**2.53**	**29.4%**	
	Stdev:	**7.20**			**51.39**				**8.9**				
	Variance:	**51.80**			**2641**				**79.06**				

Phase 2: - Electronic Learning Results - Testing group 1 with script errors marking adjusted accordingly

	Student number	Pre test score		Self Index pre knowledge	UCAS Traiff points	Previous knowledge of HVS		Age	Post test score		Self Index of post knowledge	Percentage change	Additional Comments
		Score	%			HVS Specific	Description of study		Score	%			
1	N0017770	6.0	16.7%	1		1	GCSE	18 - 25	31	67.4%	2	50.7%	
2	N0024579	4.0	11.1%	2	440	1	GCSE D/Science	18 - 25	24	52.2%	2	41.1%	
3	N0026125			3		1	A level Biology	18 - 25					Anomaly
4	N0041082	2.0	5.6%	2	260	1	GCSE	18 - 25	35	76.1%	3	70.5%	
5	N0066594	12.0	33.3%	2	300	1	GCSE	18 - 25	28	60.9%	2	27.5%	
6	N0066647	0.0	0.0%	1	260	0		18 - 25	25	54.3%	2	54.3%	
7	N0067733	8.0	22.2%	2	220	1	GCSE	18 - 25	22	47.8%	3	25.6%	
8	N0073284	8.0	22.2%	2	290	1	GCSE;	18 - 25	25	54.3%	2	32.1%	Partially Blind
9	N0076953	26.0	72.2%	4	140	1	A level Physics	18 - 25	35	76.1%	4	3.9%	
10	N0078826	24.0	66.7%	4	270	1	Cornea transplant patient	18 - 25	37	80.4%	3	13.8%	
11	N0078981	12.0	33.3%	3	430	1	A level Biology	18 - 25	24	52.2%	3	18.8%	
12	N0081568	0.0	0.0%	1	360	1	GCSE	18 - 25	16	34.8%	2	34.8%	
13	N0082363	16.0	44.4%	2	450	1	GCSE	18 - 25	34	73.9%	3	29.5%	
14	N0082821	12.0	33.3%	2	240	1	GCSE	18 - 25	30	65.2%	2	31.9%	
15	N0083050	2.0	5.6%	2	220	1	A level Physics	18 - 25	22	47.8%	3	42.3%	
16	N0083719	26.0	72.2%	3	200	1	A level Biology	18 - 25	37	80.4%	3	8.2%	
17	N0084107	14.0	38.9%	2	160	1	GCSE D/Science	18 - 25	31	67.4%	2	28.5%	

Phase 2 : - Electronic Learning Results - Testing group 2

	Student number	Pre test score		Self Index pre knowledge	UCAS Traiff points	Previous knowledge of HVS		Age	Post test score		Self Index of post knowledge	Percentage change	Additional Comments
		Score	%			HVS Specific	Description of study		Score	%			
18	GB114170	12.0	33.3%	3		1	GCSE Science	18 - 25	31	59.6%	3	26.3%	
19	N0034851	1.0	2.8%	1		0		18 - 25	20	38.5%	1	35.7%	
20	N0035345	4.0	11.1%	1		1	GCSE Science	18 - 25	12	23.1%	2	12.0%	
21	N0058570	19.0	52.8%	2	480	1	GCSE	18 - 25	41	78.8%	3	26.1%	
22	N0068773	10.0	27.8%	2	180	1	GCSE	18 - 25	16	30.8%	2	3.0%	
23	N0069517	26.0	72.2%	3	220	1	GCSE biology 2 years	18 - 25	37	71.2%	4	-1.1%	
24	N0069998	4.0	11.1%	1	200	1	GCSE D/Science	18 - 25	18	34.6%	2	23.5%	
25	N0071014	4.0	11.1%	1	120	1	GCSE Science	18 - 25	6	11.5%	1	0.4%	
26	N0073864	16.0	44.4%	2		1	Pre Gcse	18 - 25	9	17.3%	2	-27.1%	
27	N0074350	28.0	77.8%	3	250	1	A level Physics; GCSE Biolo	18 - 25	39	75.0%	4	-2.8%	
28	N0074557	4.0	11.1%	1		1	GCSE Science	18 - 25	26	50.0%	3	38.9%	
29	N0074673	13.0	36.1%	2	350	1	GCSE biology 2 years	18 - 25	24	46.2%	3	10.0%	
30	N0077290	2.0	5.6%	1	260	0		18 - 25	36	69.2%	2	63.7%	
31	N0077490	0.0	0.0%	1	210	0		18 - 25	24	46.2%	2	46.2%	
32	N0077591	18.0	50.0%	3		1	GCSE biology	18 - 25	33	63.5%	3	13.5%	
33	N0077897	7.0	19.4%	1	240	1	GCSE biology 2 years	18 - 25	25	48.1%	2	28.6%	
34	N0079071	4.0	11.1%	1	300	1	GCSE D/Science	18 - 25	27	51.9%	3	40.8%	
	Means:	10.4	28.96%	2.0	271.2	0.9			26.7	54.75%	2.5	25.8%	
	Stdev:	8.6			96.1				8.7		0.8		
	Variance:	73.8			9227				76.5				

Comparing TLM's results: Combined Calulations of Phase 1 & 2

	Pre test score		UCAS T/Points	Post test score		% Change
	Score	%		Score	%	
Means:	8.1	22.60%	230.5	27.2	49.37%	26.77%
Stdev:	7.55			9.65		
Variance:	57.0			83.5		

Comparing ELM's results: Combined Calulations of Phase 1 & 2

Combined Calulations	Pre test score		UCAS T/Points	Post test score		% Change
	Score	%		Score	%	
Means:	10.1	28.02%	267.1	29.4	56.64%	28.63%
Stdev:	7.71			9.81		
Variance:	59.4			76.5		

UCAS tariff points comparison between phases

	Phase 1	Phase 2
Means:	233.0	268.9
Stdev:	98.2	84.3
Variance:	9638	7102

UCAS tariff points comparison between packages

	TLM	ELM
Means:	230.5	267.1
Stdev:	89.5	99.1
Variance:	8007	9830

Appendix I

ANOVA statistical tables

ANOVA Statistic Tables

Pre-test Phase 1 Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	73	1692	22.72	489
ELM	25	669	26.78	320

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	239	1	239	0.53	0.47	3.94
Within Groups	42903	96	447			
Total	43142	97				

Pre-test Phase 2 Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	19	419	24.70	429
ELM	34	956	28.96	577

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	448	1	448	0.85	0.36	4.03
Within Groups	26782	51	525			
Total	27231	52				

Post-test Phase 1 Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	73	3580	48.09	323
ELM	25	1480	59.14	263

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1922	1	1922	6.24	0.01	3.94
Within Groups	29551	96	308			
Total	31473	97				

Post-test Phase 2 Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	17	921	54.75	312
ELM	33	1805	53.37	337

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3	1	3	0.01	0.92	4.04
Within Groups	15776	48	329			
Total	15779	49				

Pre-test Combined Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	90	2111	23.09	472
ELM	55	1625	28.22	461

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	760	1	760	1.62	0.20	3.90
Within Groups	69731	149	468			
Total	70491	150				

Post-test Combined Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	90	4501	49.22	321
ELM	55	3285	56.64	305

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1550	1	1550	4.92	0.03	3.91
Within Groups	45976	146	315			
Total	47527	147				

Pre-test TLM Phase Comparison Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Phase 1	73	1692	23.18	489
Phase 2	19	419	22.05	429

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	19	1	19	0.04	0.84	3.95
Within Groups	42946	90	477			
Total	42965	91				

Pre-test ELM Phase Comparison Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Phase 1	25	669	26.76	320
Phase 2	34	956	28.12	577

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	27	1	27	0.05	0.81	4.01
Within Groups	26740	57	469			
Total	26767	58				

Post-test TLM Phase Comparison Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Phase 1	73	3580	48.08	323
Phase 2	17	921	54.16	312

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	361	1	361	1.13	0.29	3.95
Within Groups	28226	88	321			
Total	28587	89				

Post-test ELM Phase Comparison Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Phase 1	25	1480	59.20	263
Phase 2	33	1805	54.70	337

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	288	1	288	0.94	0.34	4.01
Within Groups	17101	56	305			
Total	17389	57				

Single Factor Anova: UCAS tariff point comparison for phase 1 & 2 ELM

SUMMARY

Groups	Count	Sum	Average	Variance
Phase 1	19	4970	262	11158
Phase 2	26	7050	271	9227

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1006	1	1006	0.10	0.75	4.07
Within Groups	431518	43	10035			
Total	432524	44				

Single Factor Anova: Phase combined % change comparison

SUMMARY

Groups	Count	Sum	Average	Variance
TLM	90	2352	26.13	347
ELM	55	1570	28.54	471

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	198	1	198	0.50	0.48	3.91
Within Groups	56254	143	393			
Total	56452	144				

Appendix J

Questionnaire results

Student Questionnaire responses

Participant No.	Prvious use of ELM's			No. of packages used	Subject matter	Where did you use them?			Did you enjoy using them?			Effective? (scale)	ELM Stimulating compared with TLM?			This ELM's effectivness (Scale)	Interest maintained (Scale)	Motivation to learn (Scale)	Interesting comments
	Yes	No	Not Sure			Home	School	Work place	Yes	No	Not sure		Less	Same	More				
1		1														65.5	79	55	To take the eye apart, zoom feature
2	1				Software tutorials, games, encyclopedia	1	1		1			93			1	93	75	93	Visual memory stiumlated
3		1													1	75	75	75	Learning at ones own pace
4	1				Sciences		1		1			62		1		60	60	55	Supplemental to TLM
5		1											1			50	29	60	Too grand, more basic but more functionallity
6			1		Software	1				1		50		1		59	52	55	Classical music aided concentration
7		1													1	78	78	62	3D visualisation of structure aided
8			1												1	50	75	60	Photographic memory more effective means of learning
9	1			2	careers service; languages		1	1	1			88		1		75	75	75	Good teacher motivates more
10		1													1	75	100	65	Music create good ambience for learning
11			1	4	Art & design programming; web based	1			1			74			1	75	70	65	more engaging medium
12		1												1		75	70	65	
13	1			2	for learning difficulties		1			1		25	1			48	80	75	
14	1			1	Driving theory	1			1			100			1	80	75	60	music too relaxing
15		1												1		80	75	50	music distracting, female voice
16		1													1	75	60	40	visaul learning difficult to maintain interest
17	1				electric curcuits / wave motion		1		1			50	1			58	75	65	
18	1			2	History, Science		1		1			70			1	70	75	74	
19	1			3	Health & safety, fire safety, revision	1		1	1			70		1		65	55	62	dull narators voice, female voice
20	1			2	software tutorials	1			1			75			1	50	92	75	v.motivating, syncro spoken words with text
21	1			2	Geography, science GCSE	1	1					80	1			30	75	65	Intresting but difficult to absorb
22	1			2	maths, physics	1		1	1			78		1		65	75	63	moving images stimulating
23		1												1		65	75	58	
24		1												1		60	75	65	
25			1												1	65	57	45	easier to understand structure
26	1				driving test, software tutorials, GCSE's	1	1								1	65	50	45	multimedia aspect keeps your attention
27		1												1		50	50	49	
28	1			20	computer software, exam revision	1	1		1			75		1		50	25	42	secondary education not FE
29	1			3	software packages	1					1	50			1	60	50	25	Interesting
30	1			2	maths & science		1		1			75			1	75	75	65	Helped understanding
31	1				science maths	1	1				1	50			1	75	75	50	technical terms difficult to understand
32	1			4	maths & science & english		1		1			75			1	75	75	65	improved understanding
33	1				driving theory	1			1			70			1	60	87	80	facts easier retained when listened too
34		1													1	78	50	60	easier to understand structure
35	1			2	driving theory, spanish lessons						1	45				65	20	15	need for interactive element
36			1												1	75	60	75	
37	1			14	biology, photography	1	1		1			100				78	80	60	
38			1												1	75	80	85	easier to understand structure
39			1												1	78	100	80	encouraged attention
40		1													1	78	100	78	
41		1													1	80	72	68	
42	1			1	pc programs, web based					1		60		1		62	75	60	
43	1			2	driving, photoshop	1	1			1		65			1	60	25	50	
44			1		science		1				1	50			1	65	78	55	music at times distracting
45	1			2	computer software		1		1			65		1		78	78	65	layout and function easy to understand
46		1													1	90	95	90	effortless learning
47	1			3	computer software		1		1			78	1			50	100	60	understanding of sturcture and movement
48	1			3	science, engineering		1		1			69		1		72	65	60	
49	1			3	GCSE	1	1		1			65			1	51	75	70	more enjoyable & accessible then TLM
50	1			1	driving theory test	1			1			70			1	70	70	70	
51		1												1		70	100	75	person not impressed by graphics & design may find it not very interesting
52	1			1	web design			1			1	55		1		60	50	60	time saving for all
53		1												1		50	50		
54																			
55																			
56																			
Totals:	28	17	8	3.5	11 software;	17	19	4	20	4	5	67.7	5	17	28	66.7	70.0	62.3	
						60.7	67.9	14.3	71.4	14.3	17.9								

Appendix K – Analysis of Variance (ANOVA) explained

In general, the purpose of analysis of variance (ANOVA) is to test for significant differences between means. Comparing only two means the ANOVA will give the same results as a t test for independent samples (comparing two different groups of cases or observations). ANOVA was chosen in this instance due to it being a statistical analysis that had been used in studied papers during the research and was therefore investigated. It was also chosen due to the ease of calculating the statistic in the statistical software (Microsoft Excel) and the efficient output of the statistical tables in this program. The name Analysis of Variance comes from the fact that in order to test for statistical significance between means of results, a comparison of the variances is carried out.

Below is a typical ANOVA table result:

SUMMARY				
Groups	***Count***	***Sum***	***Average***	***Variance***
TLM	**90**	**4501**	**49.22**	**321**
ELM	**58**	**3285**	**56.64**	**305**

The table firstly presents a summary of statistics, including the sample size, sum of the samples, mean of the whole sample and the variance.

ANOVA					
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***
Effect – Between groups	**1550**	**1**	**1550**	**4.92**	**0.03**
Error – Within groups	**45976**	**146**	**315**		
Total	**47527**	**147**			

SS	=	Sum of squares
df	=	Degrees of freedom
MS	=	Mean Square effect / error
F	=	F distribution
P-Value	=	Probability value referred to as 'statistical significance'

At the heart of ANOVA is the fact that variances can be divided up, that is, partitioned. The variance is computed as the sum of squared deviations from the overall mean, divided by n-,1 sample size minus one. Given a certain n, the variance is a function of the sums of squares (deviation), or SS for short. Partitioning of variance works as follows. Consider the following data set:

	Group 1	Group 2
Observation 1	2	6
Observation 2	3	7
Observation 3	1	5
Mean	2	6
Sums of Squares (SS)	2	2
Overall Mean	4	
Total Sums of Squares	28	

The means for the two groups are quite different (2 and 6, respectively). The sums of squares within each group are equal to 2. Adding them together, we get 4. If we now repeat these computations, ignoring group membership, that is, if we compute the total SS based on the overall mean, we get the number 28. In other words, computing the variance (sums of squares) based on the within-group variability yields a much smaller estimate of variance than computing it based on the total variability (the overall mean). The reason for this in the above example is that there is a large difference between means, and it is this difference that accounts for the difference in the SS. Performing an ANOVA on the above data, would result in the following table:

ANOVA	**MAIN EFFECT**				
	SS	**df**	**MS**	**F**	**p**
Effect – Between group	24.0	1	24.0	24.0	.008
Error – Within group	4.0	4	1.0		

In the above table the total SS (28) was partitioned into the SS due to within-group variability (2+2=4) and variability due to differences between means (28-(2+2)=24).

The within-group variability (SS) is usually referred to as Error variance. This term denotes the fact that we cannot readily explain or account for it in the current design. However, the SS Effect we can explain. Namely, it is due to the differences in means between the groups. Put another way, group membership explains this variability because it is due to the differences in means.

Degrees of freedom are calculated from the size of the sample. They are a measure of the amount of information from the sample data that has been used up. Every time a statistic is calculated from a sample, one degree of freedom is used up.

Significance testing

In the above a comparison is made of the variance due to the between- groups variability (called *Mean Square Effect*, or MS_{effect}) with the within- group variability (called *Mean Square Error*, or Ms_{error};). Under the null hypothesis (that there are no mean differences between groups in the population), we would expect some minor random fluctuation in the means for the two groups when taking small samples (as in the above example). Therefore, under the null hypothesis, the variance estimated based on within-group variability should be almost equivalent to the variance due to between-groups variability. A comparison may be made between the two estimates of variance via an F test, which tests whether the ratio of the two variance estimates is significantly greater than 1. In the above example, this test is highly significant, and we would in fact conclude that the means for the two groups are significantly different from each other.

To summarise the discussion, the purpose of analysis of variance is to test differences in means (for groups or variables) for statistical significance. This is accomplished by analysing the variance, that is, by partitioning the total variance into the component that is due to true random error (i.e., within- group *SS*) and the components that are due to differences between means. These latter variance components are then tested for statistical significance, and, if significant, we reject the null hypothesis of no differences between means, and accept the alternative hypothesis that the means are different from each other.