

DEPARTMENT OF COMPUTER SCIENCE

**The development and application of multimedia in learning: A
Survey of Literature**

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in learning:**

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1.0 Introduction

Multimedia applications used in education and training are a relatively recent phenomenon. The development and use of multimedia has been influenced by many social and economic factors related to the enormous growth of computing in the world today. The roots of multimedia however have a relatively long history which stretches back to early applications of the computer in the 1950s and 1960s. The history of the development of learning theories and applications is also relevant to the development and application of multimedia technology in education. These theories and their application to learning and training methods may be traced from the early days of psychological investigations at the turn of the last century. It is important to consider how the understanding of the underlying principles of learning and the development of computer technology have interacted in the development of multimedia in education. Multimedia offers great potential as a tool in learning. The object of this report is to survey the development of multimedia used in education and to look at issues related to its role.

The perception of quality of multimedia applications is highly complex and can be shown to be influenced by many factors. These include the personal characteristics of the user (for example prior skill, language level, individual learning style, motivation etc.), the type of learning application, the interaction between the user and system, design issues relating to the media, the delivery of the media, the learning environment and pedagogical principles associated with learning taking place, both internal and external to the application. The review aims to survey some of the current thinking on these and related issues. Given the complexity of the subject, the evaluation of multimedia learning applications is therefore extremely important in the design process and to ensure that there is benefit in its use. Much of the testing and evaluation of computer based learning materials in the past has centred on comparison between performance on the system under study and delivery either by traditional classroom methods or by another medium. This practice is discussed at the end of this review in consideration of the issues approached..

A major problem encountered in describing or comparing learning applications is the terminology used. This has developed largely in UK and USA in academic and commercial organisations over many years. There is a wide range of usage of the terms, which probably reflects the diversity of origins and long time span over which systems developed. It is important that some of the main definitions of terms and distinctions between them is established for the purposes of this review.

1.1 Teaching, training and education and learning: distinctions and definitions

The distinction between teaching, training and learning has become less important in Further Education in recent years. This is largely because students have to take a greater responsibility for acquiring the skills and knowledge they need in a rapidly changing world. Educators (teachers, trainers, facilitators and curriculum managers) are currently engaged in finding ways of empowering the learner to control their own learning effectively. The use of flexible, accessible multimedia learning materials is considered to be important in this process (Further Education Funding Council, 1996). Despite this change of emphasis from teaching to learning, an older terminology applied to teaching and training is still used in describing these new learning systems. The following sets out some definitions and explores the use of the terminology.

Learning

Mayer stated that learning 'is the relatively permanent change in a person's knowledge or behaviour due to experience' (Mayer 1982). This simple definition is used as the basis for the use of the term in this review. In its widest sense, learning is the cause of any change in behaviour or state of knowledge of a person due to the receipt of information through the senses. It may also refer to changes due to the application of practice or of thinking.

Teaching

Classically, teaching has been defined usually in the transitive case, as an action performed by one system upon another to cause learning. Except in the case of self-teaching, there the notion of a passive recipient of knowledge and an active provider of the same. The teacher is considered to act upon the student in some way, leading to the transfer of knowledge or skill. Teaching today is often considered to be largely about helping people to learn for themselves.

Skill

Teaching and training have been defined in terms of the transfer of skills. The concept of a skill is difficult to define largely because the term has been applied widely in many contexts. The Department of Employment's Glossary of Training Terms (1971) suggests that 'Skills may be described as perceptual, motor, manual, intellectual, social etc. according to the context or the most important aspect of the skill pattern.' Learning a skill then is seen as being far wider than learning a simple task. Holding sees many skills as perceptual-motor tasks which may be located along a continuum ranging from purely perceptual, where responding to a stimulus is the dominant feature of the skill, to purely motor skills which involve only body movements. Cognitive

skills are concerned with decision making and reasoning (Holding 1965). Even these skills however are seen to contain some components of perceptual-motor skills. Such categorizations however are considered only as descriptors of the dominant psychological features of tasks by Patrick (1992).

Education

The concept of education involves a much wider social system, though its use is often restricted simply to mean teaching or learning in general. Often education is seen as a method of excluding persons from a process rather than a process designed for qualifying or preparing an individual. It has been suggested by Glaser (1962) that the aims of education include maximization of individual differences, whereas training minimizes this and seeks to achieve standards of performance between individuals. The complex processes of socialization are wrapped up in education, which takes place in a social context (Somekh 1996).

Teaching and Training and Education

It may be argued that the terms 'teaching and training' are used to imply systematic efforts to achieve specific measurable objectives, whereas the term 'education' is used to imply the improvement in general levels of competencies in individuals. Training has been defined as 'the systematic acquisition of skills, rules, concepts, or attitudes that result in improved performance in another environment' (Goldstein 1993). This definition, although behaviouristic in the way it is stated, benefits from its potentially measurable requirement to improve performance. It is easier to specify outcomes in terms of training goals rather than educational goals for this reason. Patrick takes a wider view of training, 'the aim of training is to develop new skills, knowledge or expertise' (Patrick 1992). Improvements in knowledge are likely to be more difficult to assess than in performance.

In summary, it appears that the term 'training' is often used to relate to teaching and learning of specific skills or knowledge about fairly limited systems and that 'education' is often used to imply a larger more general system of knowledge acquisition and qualification. The terms 'teaching and learning' are used to explain the complex ways in which education (in general) or training (specific skills) takes place in people. In recent times the distinction between teaching and learning is becoming less important. This is because the importance of teaching in the overall process is being challenged. The term 'skill' is often used to mean task, but may also be used to refer to complex cognitive skills such as decision making.

The terminology used in describing the learning process has evolved over many years and its use reflects its diverse origins. Terms are used in this review in the context in which they were first used in the publication under

discussion. It is possible however that the meaning of the term or how it is used may be different from that of today. In today's usage, learning is held to be central and the terms 'teaching, training and education' are less important. Theories of learning are more important than theories of education, training or teaching for this reason.

2.0 The psychology of learning

Theories of learning have influenced the design of learning and training programs for many years and are therefore especially important to those interested in computer based teaching, training and learning for this reason. The design of such programs often relies upon the use of a learning theory in order to provide a structure for the learning material or program. Ideas about how we learn can be used to improve the presentation and organization of learning however it is delivered.

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

2.1 Historical perspective (early theories of learning)

Early theories of learning were concerned with how subjects responded to stimuli within their environments and was largely tied up with the behaviourist school of psychology. The importance of behaviour modification in learning was stressed and the concept of reinforcement of behaviour was used to explain learning. It is likely that the rise of Behaviourism was fired by a need to introduce scientific methodology into psychology. The work of Wundt and James had been concerned with the mental processes of conscious, mainly by introspection (James 1890, 1893). Freud had concerned himself with the unconscious with the development of psychoanalytical techniques (Freud 1950). Scientific psychologists were concerned with the application of scientific techniques to the study of behaviour (Cattell 1896). The mental processes underlying behaviour were to be ignored as these were not susceptible to study. Only behaviour could be measured objectively and therefore be the subject of experimentation. From such experiments it was intended that laws of behaviour be derived. Many *laws* of behaviour as applied to learning were elucidated during this period, which occupied the whole of the first part of the twentieth century and still continues.

Practical application of the new science of psychology to education was the concern of the Progressive school and the work of John Dewey (Dewey 1900). In his important paper on the reflex arc, Dewey introduced the notion that stimulus and response could be connected in behaviour without recourse to underlying mental processes. Even complex processes such as perception and decision making could be explained as coordinated complex behaviours (Dewey 1896). These ideas had a profound influence on the study of learning during the next fifty or so years.

Thorndyke, a student of James, concentrated on animal behaviour which led to the formation of a Stimulus-Response (S-R) psychology. This work he summarized in *Animal Intelligence* (Thorndyke 1911/65). Thorndyke established the principles of operant conditioning or learning, where appropriate responses to a stimulus are rewarded and reinforced leading to learning. Other responses which are not rewarded are extinguished. This approach was further developed by Hull (Hull 1943) where reinforcement was linked to the satisfaction of biological drives. Skinner developed the application of reinforcement in operant conditioning to learning in humans (Skinner 1953). This has been used extensively in the development of training programs in the 1950s and 1960s, often referred to as programmed learning. In his 1954 paper, 'The Science of Learning and the Art of Teaching', Skinner emphasized the need to make use of the principles of reinforcement in teaching and learning (Skinner 1954). Complex linear teaching programs were devised, incorporating Skinnerian principles in their construction.

Other workers were more concerned with the diagnostic value of errors in learning. Skinner was less concerned with errors and more concerned with reinforcing success and discouraging any error. Remedial training systems were devised by Crowder which did not avoid error, but rather used it to identify potential remedies (Crowder 1960). This in some ways went against the behaviourist tradition. Branching programs of learning were devised to provide competence based paths through training material. This was very much a movement away from simple S-R reinforcements in learning emphasized during the previous fifty or so years. During this period there were many objections to operant conditioning for several reasons. These are summarized by Postman who deals with philosophical, empirical and logical objections to the theory (Postman 1947). Not least of these was how far the supposed psychological laws obtained from animal experiments could be applied to human learning. It was also difficult in human experiments to separate reward from the information and motivational content of the situation. For example a correct response may elicit a reward. This informs the subject that it was a correct response (information) and also motivates future performance. Learning may be considered, in the light of this, to involve far more than the acquisition of simple Skinnerian S-R connections. It is more complex and involves purely mental concepts such as motivation

and the analysis of information which are difficult to explain solely in terms of behaviour.

Behaviourism has the learner as a passive recipient of a training program. Much of learning however is interactive and involves a contribution to the process from the learner. This feature is not explained well in the behaviourist theory. There is a general acceptance that an *understanding* of such theories is of little use in the design of modern training programs for humans today, though behaviourist principles are still employed in the design of such applications. Indeed when acquisition of simple task related skills is all that is required, learning based upon behaviourist principles may be very effective.

The information processing model of skill favoured in the 1960s and 1970s led to the combination of the concepts of information and feedback control into learning (Welford 1968). The output from a system was used to control the future input to the system. The communication theory as summarized by Fitts and Posner (1967) was used as a metaphor for human skilled performance. The quantitative measures of information processing were able to be derived and applied to different skilled tasks. Such signal processing concepts as noise, distortion and transmission rate of information were applied to learning of skilled tasks. The concept of information processing, and feedback loops was applied to human sensori-motor systems (Welford 1968). Learning was broken into systems and processes such as signal detection, which can be considered as discrimination of signal against background noise for example, or how subject attended to signals presented, or interpreted the signal. Aitkin and Lau used this concept in training programs where trainees were informed when to expect signals (Aitkin and Lau 1967).

Adams (1968) and Annett (1969) looked at the role of feedback in the learning process and in the control of skilled tasks. Various types of feedback were identified. Intrinsic (proprio-receptive) and Extrinsic (auditory, visual) feedback were distinguished. Intrinsic feedback was that available to a person in the normal execution of a task. Extrinsic feedback is feedback introduced artificially to assist in training a person for a task (Stammers and Patrick 1975).

The promise of behaviourism as a way of understanding learning by breaking complex systems into chains of simple S-R links clearly failed to explain many of the interesting aspects of how humans learn. The mystery of the human mind is clearly involved in the learning process and a system that ignores mental aspects such as thinking could have little hope of success. The next section looks at later attempts at understanding how we learn that take into account the role of our minds in the process.

2.2 Cognitive Psychology and Learning Theories

Behaviourism did not take into account the mind of the learner. The feedback theories of learning were quantifiable yet treated the mind or at least the recipient of learning as a machine and learning as signals to be processed by the machine. Feedback theories have been important in the design of modern learning programs, where extrinsic feedback, e.g. knowledge of results, is important in influencing performance.

Arguably as a reaction to the mindless theories of behaviourism, where learning was passive and autonomic, a new area of experimental psychology, later known as cognitive psychology arose in the 1970s. The learner was seen as using active mental processes to search for understanding. These strategies, perspectives and interpretations were used by the learner to create learning individually (Patrick 1992). Much research took place to support this view of learning, for example it was shown that peoples' expectations affected what is learned and remembered (Bower et al 1979). Broadbent suggested that the information processing theories of learning ignored the influence of learner strategies and tended to hide the flexibility of performance and the variety of resources which are used by the learner in learning (Broadbent 1987). The goal of training then may involve ensuring that appropriate cognitive strategies exist for the development of learning in an individual.

2.3 The Application of Learning theory to Computer Aided Learning

The design of computer based learning materials involves several stages and has been described fully by Alessi and Trollip (1991). One major stage in the authoring process is the mapping of a learning theory onto the course material to produce a structure for the course. Once the course material to be delivered has been specified, the course structure determines the ways in which learning is presented and controls important features such as learner participation and interaction. The course structure and how it relates to underlying learning theory is an extremely important feature of learning material.

Various theories of skill acquisition and learning have been applied to the design of training. The emphasis in the past has very much been on the design of training and not the design of learning. Patrick (1992) for example, contrasts theories of skill acquisition with theories of training design. Skill acquisition theories look specifically at the process of learning according to Patrick, and do not approach issues as how to design training per se. It is evident that there is no simple way to apply a theory of learning to the design of training. Patrick suggests that this is because no comprehensive and validated set of design principles yet exists that can be applied directly to the design of training. In the application of learning theories to design of training,

Patrick argues that the application of any particular learning theory to the design of learning should not be regarded as being exclusive. Its application should depend rather on the tasks and situations to be addressed. The appropriateness of a learning theory is stressed by Logan in an analogy between the use of learning theories and the use of statistical tests. 'When two different tests can be used on the same data, one can ask which is more powerful and accurate' (Logan 1988). In much the same way, the use of a learning theory in the design of training is seen as a choice that depends on the training situation.

There are important reasons why theories of learning and instruction cannot be used directly in the design of authoring systems. The conceptual layer between the application and the user (the instructional theory) is poorly understood and cannot be used for the purpose of design according to Ohlson (1993). The widely held suggestion therefore that cognitive theory should have implication for design of CBI is only weakly supported by the evidence according to Ohlson. Authoring systems might be built on a theory of design rather than learning and instruction theories. This idea has appeal to some designers since such theories are likely to be simpler and easier to understand than theories of learning.

Atkins (1993) presents a summary of research into learning theories applied to interactive courseware and poses the question as to what psychology can teach the next generation of multimedia technologists about how human beings learn (Atkins 1993). The behaviourist view is examined by Atkins and linked to an objectivist view of knowledge. The contribution of cognitive psychology is examined in terms of information processing and social constructivist models. Four major issues are by addressed by Atkins: the suitability of multimedia applications for some types of training, the type of tutoring support provided to the learner, the efficacy of multimedia courseware in serving very different knowledge structures as in the sciences and arts and the nature of the partnership between the user and the application in a learning task.

Learning theories then are important in the design of learning and training materials. There is some debate as to how they can be applied in practice to the design of learning. Two types of application of learning theory have emerged in recent times, the instructivist school, based on behaviourist principles and constructivist ideas that rely on the application of cognitive psychological ideas. The next two sections, 2.3.1 and 2.3.2 look at the ways in which these have been applied.

2.3.1 Behaviourism

In this system, appropriate learning behaviour is shaped by serially structured sequences that model, establish and reinforce the relevant associations in the

mind of the learner. The main features of behaviourist theory as applied to the design of training are outlined below.

- Simple associations are linked together in chains to yield mastery of more complex procedures.
- Characteristics of instructional design may be identified based on the behaviourist tradition..
- There are prior definitions of objectives with explicit and measurable criteria for assessment of performance.
- Material is broken down into small logical steps.
- Material is often presented as a rule, principal, formula or definition. followed by examples. Understanding is reinforced by giving positive examples which support the rule etc. followed by negative examples to establish conceptual boundaries.
- Activities are sequenced for increasing difficulty or complexity.
- A frequent review with check tests or repeat practice with feedback to build up proficiency is provided.
- A low error rate is aimed for in the course, and a remedial loop back through material is available.
- Reinforcement messages, are provided, both intrinsic or extrinsic to the training material.
- There is an opportunity to observe, review or copy desired behaviour.
- The sequence and pacing of material is often outside the control of the learner.
- The learner may be routed to miss or repeat sections according to performance in prior tests or in learning activities in the program.

Many of the features available in early behaviourist training systems may be seen in learning applications today. For example many provide performance feedback to learners. The use of feedback has been investigated in learning programs. Hannafin and colleagues have shown that learning increased as the amount of performance feedback to learners increased. There was generally found to be a trade off between the amount of feedback and the efficiency of learning however, since the use of feedback increased the time required to complete the learning (Hannafin et al 1986; Hannafin and Colamaio 1987). Definitions of training efficiency in the literature are not

consistent but refer in general to how much time is taken to deliver a skill or knowledge. Efficient training is fast according to Hannafin.

Skepticism about behaviourism increased in the 1960s and 1970s and the idea was beginning to emerge based largely on experience and research findings that many aspects of learning could not be explained by the use or application of behaviourist theories of learning. Attempts to learn meaningful material by rote memorization, for example, are not effective according to Craik and Watkins (1973) and requesting people to learn rarely results in superior performance compared to study with no request (Nelson 1976). Sweeney has shown that the use of mnemonics and strategies that add meaning to material vastly improve learning (Sweeney and Bellezza 1982). Behaviourism ignores anything that occurs in between the stimulus and response. Clearly studies that suggest learning strategies are effective do not fit well with Behaviourist ideas. It is accepted though that behaviourism can be applied to some aspects of the delivery of learning. 'Overall now there is now probably sufficient evidence to show that learning can be efficiently accomplished by the use of the behaviourist characteristics,' (Atkins 1993).

The application of behaviourism to the design of learning may indeed result in measurable improvement in performance. Learning however, may also be considered to relate to changes in the mental state of a person. People learn when they understand concepts, integrate new ideas into what they already know or explain ideas to themselves and to others. These mental features of learning are difficult to conceive of in terms of behaviour alone. Behaviourism cannot explain almost all of what goes on in people's minds when they learn. Cognitive psychology however can provide useful insight into these processes. Cognitive theories may therefore be used in the structure and design of learning that is interesting and involves the learner actively in the learning process. The next section considers features of cognitive theories that make them important in the design of learning.

2.3.2 Cognitive theories

The term 'cognitive' is applied to theories of information processing that are concerned with what happens in between the stimulus and the response. They include weak theories of information processing and social constructivist theories (Atkins 1993).

At least three stages or parts are involved in weak information processing theories: selective attention, active mental processing and the structuring and encoding of new information into long term memory. Metacognition, defined as awareness of ones own learning is often involved in the selection of learning strategies. Constructivist theories of learning see learning as the 'subjective construction of meaning from experience in specific contexts' (Somekh 1996). In such theories, according to Somekh, the teacher is a negotiator or facilitator of shared understandings and not merely the

transmitter of knowledge in the form of facts or rules. The classroom and laboratory may be seen by some as artificial and real learning can only take place in realistic settings, or in the community in which the learner lives (Somekh 1996). Knowledge is not externally defined in such theories, but is something which is socially constructed, context specific and not consistent across time or groups of learners.

Early cognitive theories of learning have been seen as candidates for application to the design of learning. Bruner for example proposed a layer theory of instruction (Bruner 1966a). Such a theory of instruction may be sandwiched between a learning theory and the practice of design. For many designers however, it is still difficult to see how the high level design features necessary in the application can be obtained from the low level theory of learning. This limitation however may be overcome however and Ohlson stresses the need to focus on promising solutions in cognitive theory when designing learning applications (Ohlson 1993). Cognitive theory has the potential to impact on design in two different ways: by guiding the generation process towards best design candidates and by facilitating evaluation according to Ohlson.

The specific application of cognitive learning theory to the development of instructional principles has been approached in several ways by authors. Some ideas and guidelines that have been used in the past are given below.

- Advanced organizers (Ausubel 1963, 1968) and (Reigeluth and Stein 1983) Student internalizes an epitome, (the small foundation of an idea) which is expanded, differentiated and elaborated. In this way new ideas are integrated into existing knowledge.
- Cognitive conflict (Piaget 1985). Student driven to learn when their cognitive structures are insufficient to handle a situation. Instructional principal is that cognitive conflicts should be introduced deliberately to motivate learning.
- Succession of representations (Bruner 1966b) Enactive encoding, iconic encoding and symbolic encoding enable action, visualization and abstract thought respectively. Physical objects used to teach abstract principles e.g. in mathematics.
- Goal hierarchies (Anderson et al 1990). Skills are analyzed into a set of goals and sub goals. The learner should be told of the sub goals explicitly. In this way they are involved in and take responsibility for learning.

General methods or guidelines in which cognitive theories can be used in the design of learning have been suggested by several authors. For example some general characteristics of instructional design that have a cognitive orientation are given by Atkins:

- Orientation to tune in the learner, helping to attend to new information. The aim is to hold new information for longer in short term memory (STM).
- Advance organizers at the start of the material so that the learner can make sense of and organise new information to come.
- Metacognitive devices such as advice, help facilities and suggestions for more efficient processing of information are provided.
- Learners are required to engage actively with the material. There are frequent decision points, games, simulations and results of decisions are seen immediately.
- Use of compare and contrast or observe and identify activities. Learners are expected to analyze, synthesize, summarize, describe and solve problems.
- Users are expected to explore and discover environments for themselves.
- Learners are moved back and forth between symbolic representation and real life.
- Learners are expected to build up their own hypotheses, explanations, definitions, categories, rules etc., based on their own experiences.
- There is a provision of microworlds and simulations with variables/factors under user control.
- A safe learning environment is provided in which mistakes can be made and learning gained from them.
- Interaction between learner and expert is supported.

The application of the above cognitive principles to design would be expected to support and encourage active learning. They have in common the requirement to engage the learner actively in thinking. Atkins suggests however that the field is still an emerging one and that empirical evidence is still patchy, though more substantial than five years ago. Multimedia developers are however often more interested in cost benefit analysis than pure questions of the application of cognition according to Atkins.

Despite Atkin's emphasis on cognitive learning theories, the historical split between behaviourism and cognitive approaches does not assist the development of learning materials according to Atkins. There is at present no single coherent model of learning to support the design of learning applications.

The lack of a single universal theory of learning may be because learning is a complex system that involves the acquisition of a wide range of reflexes, tasks, skills, concepts, ideas and performances. It is unlikely that any single theory will encompass it all. Practical instructional design might involve picking the best features of a theory of learning and apply this to the design of learning. It is now possible to understand how Logan's ideas on the appropriateness of a learning theory as a candidate for design decisions as outlined in section 2.3 may be applied (Logan 1988). It is possible to select features from a wide range of cognitive theories of learning and apply them to learning material design. These are Ohlson's best candidates toward which design should be guided. This still leaves us the question as to how we know what the best features are. Certainly learning that involves changes in thinking is best facilitated by the application of constructivist theories of learning.

Cognitive theories of learning are important because they concern themselves with mental processes in the learner. Computer applications may also be used to model mental processes in somewhat different ways. The marriage of computer and learning theory can add additional layers of richness to the design of learning materials.

Wild has looked at the relationship between mental models and computer models in learning. Wild looks at the ways in which children use spreadsheet applications to build their own conceptual models. It is suggested that the process of building computer models may provide direct support for the process of constructing mental models (Wild 1996). Mental models are described by Getner and Stevens as a means of explaining human understanding (Getner and Stevens 1983), and the 'mediating intervention between perception and action'. Wild states that 'if we are to encourage development of appropriate, strong and accurate mental models on the part of learners, we probably need to provide opportunities for learners to consciously (rather than unconsciously) construct and evaluate their own mental models'. This is completely in line with a constructivist theory of learning.

Other ways that authors have tried to use ideas from cognitive psychology in the development of learning applications includes the Intelligent Educational System. Such systems are designed to present and configure learning for the learner, based on educational decisions made within the application as opposed to computing decisions based on the technology. Cummings (1993) states that discussion level interaction between the learner and the system is facilitated in such systems by a module to support interactions with the learner. This is used to augment the task level interactions found in computer applications. Task level interactions are simple interactions which take place on the surface of the learning process, as in simple skills and tasks. Discussion level interactions are deeper and involve the learner thinking

about the learning process and involve cognition. Cummings observes that a conception of learning in terms of apprenticeship is widely accepted. This idea of situating learning in context, as in an apprenticeship is an important idea in cognitive theories of learning. Cummings discusses the relationship between task level (TL) and deeper discussion level (DL) learning. Cummings suggests that there is a need to focus research attention on the more complex and interesting DL interactions between learners and computers and less on the easier task level interactions.

Others have looked at how cognitive skills may be applied to different types of learning. For example, Schoenfeld (1985) identified four components of mathematical expertise:

- Resources: facts, skills, procedures, memory for a problem
- Heuristics: specialization's of these to the domain.
- Control: managing, monitoring, shifting tack, and judging.
- Beliefs: expectations as to what is required, attitudes to problems, proof building.

The identification of the cognitive components of skills that are required in mathematics may be used to configure learning better within complex domains. It is important to use ideas such as these to provide the designers of learning with guidelines to assist in decisions as to the structure of such applications.

The development of metalevel skills are important in learning according to Collins and colleagues (Collins et al 1989). Metalevel skills in learning are those skills often described in terms of the learner being able to look down on their own learning, as if from above. The development of these skills are widely held to be important in constructivist theories of learning. Authors have looked at ways to support the development of metacognitive skills in learning.

To this end, Park and Hannafin presents the following 20 empirically derived guidelines they suggest be used in the application of constructivist theories of learning to the development of learning applications.

- Related prior knowledge is the single most powerful influence in mediating subsequent learning.
- New knowledge becomes meaningful when integrated into existing knowledge.
- Learning is influenced by the supplied organization of concepts to be learned.
- Knowledge to be learned needs to be organized in ways that reflect differences in learner familiarity with lesson content, the nature of the learning task and assumptions about the structure of knowledge.
- Knowledge utility improves as processing and understanding deepen.

- Knowledge is best integrated when unfamiliar concepts can be related to familiar ones.
- Learning improves as the number of *complimentary* stimuli used to represent learning content increases.
- Learning improves as the amount of invested mental effort increases.
- Learning improves as the competition for similar cognitive resources decreases and vice versa.
- Transfer improves when knowledge is situated in authentic contexts.
- Knowledge flexibility increases as the number of perspectives on a topic increases and the conditional nature of the knowledge is understood.
- Knowledge of details improves as instructional activities are more explicit, whilst understanding improves as the activities are more integrated.
- Feedback increases the likelihood of response relevant lesson content and decreases the likelihood of learning response irrelevant lesson content.
- Shifts in attention improve the learning of related concepts.
- Learners become disoriented and confused when procedures are complex, insufficient or inconsistent.
- Visual representation of lesson content and structure improve the learner awareness of both the conceptual relationships and procedural requirements of a learning system.
- Individuals vary widely in their need for guidance.
- Learning systems are most efficient when they adapt to relevant individual differences.
- Metacognitive demands are greater for loosely structured learning environments than for highly structured ones.
- Learning is facilitated when system features are functionally self evident, logically organized, easily accessible and readily deployed.

(Park and Hannafin 1993).

The application of the above set of guidelines in the development of learning applications will help to ensure that the learning application is based on constructivist theories of learning and will support the development of metalevel skills.

In practice, it is not always possible to make exclusive use of constructivist learning when designing applications. Often large sections of courses are based upon Skinnerian principles and are instructivist in their nature, for a variety of reasons. There is no single recognized way of thinking about the application of learning theories to design according to Somekh (1996). Somekh examines the relationship between learning applications with reference both to Skinnerian and cognitive theories of learning. Applications of cognitive theories that supports constructive learning are more difficult to devise, though more interesting. This may well explain why Skinnerian concepts still find their way into the design of learning applications. Evaluation of constructivist learning material should focus on whether or not and the

extent to which learning takes place. It would be an interesting possibility to apply Park and Hannafin's guidelines to the evaluation of such material.

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

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

(Somekh 1996)

The development of practical guidelines such as those presented in the preceding section, based on sound constructivist learning theory is important in the application of theory to practical design. Other methods of applying 'low level' learning theories to design have emerged. Richards (1996) for example states that of the many models of learning that exist, few are applied to software design. This may stem from the abstract and complex nature of psychological models according to Richards. There is a need for simplified models of learning and from which simple guidelines for implementation may be derived. The model adopted by Richards is the 'spreading ripples' model of learning (Richards 1996).

The following summarizes the stages in the spreading ripples model:

- Wanting
- Doing
- Feedback
- Digesting.

From these simple stages, eight guidelines are identified by Richards, two for each of the stages.

- Stage: **Wanting**
Guideline: Wanting must be consciously programmed into courseware.
Guideline: This is done by increasing value or increasing enjoyment.
- Stage: **Doing**
Guideline: Avoid passive interaction.
Guideline: Support practice and or trial and error learning.
- Stage: **Feedback**
Guideline: Provide students with a sense of progression.
Guideline: Encourage use within a social context.

- Stage: **Digesting**
 Guideline: Embed computer based evaluation into the application.
 Guideline: Encourage reflection away from the computer environment.

(Richards 1996)

Richard's ideas are interesting because they show how simple theories of learning are able to generate powerful guidelines for the design of learning. The stages identified in Richard's model are cognitive in the most part, since even the 'doing' stage avoids passive interaction and supports non-behaviourist trial and error learning. Behaviourism seeks to reinforce the correct answer and discourages the important process of learning from mistakes.

Other researchers have selected more complex theories to the design of learning. Fitzgerald and colleagues for example have applied the cognitive flexibility (CF) theory to the design and evaluation of multimedia applications. CF theory is a constructivist theory that emphasises real world complexity and the ill-structuredness of learning. Ill structured problems are more complex and require cognitive flexibility for understanding them (Fitzgerald et al 1997). The main difference between CF theory and other constructivist theories of learning is the change in emphasis from developing a knowledge structure based on existing knowledge in other theories to the flexible adaptation of pre existing knowledge to fit new needs of a situation in CF theory. Features of interactive multimedia and hypermedia can be used to explore different paths, to link information together in a variety of different ways and to develop personalised explanations and analogies.

There are many ways that learning theories have been applied to the design and development of learning applications. The choice of any specific theory it has been argued is less important perhaps than the process itself. Mental models and their relationship to computer models suggest how learning might be configured in modern computer applications to support important mental processes such as metacognition. Interactive features available on computers today allows complex ideas from cognitive learning theory to be implemented as in the example of CF theory.

Learning theories however are generalisations about the ways in which human beings learn. Generalisations are important in finding out general principles for wide application in design and for use in structuring learning. The ability to apply rules and guidelines to the design of learning is extremely important, since learning it has been argued, must be structured to be effective. Human beings however are also individuals and as such respond strongly to individual stimuli. The power of the modern computer can allow learning to be configured for specific individual characteristics of the learner. Individualized learning might then be superimposed upon general structures derived from the general principles of learning theories. Many aspects of the

individual may be used to configure learning. Promising candidates include an individual's learning style.

2.4 Learning styles and strategies

A learning style or strategy is a characteristic of an individual and is important in the development of learning applications for several reasons. In education today, open and flexible learning systems are in use. Within such systems, learning processes are often seen as being more important than teaching techniques. The skills required to learn are seen as being central to these flexible methods and to the notion of the learner taking responsibility for their own learning. Learning styles are also seen in terms of egalitarian concepts, focusing rather on individual strengths and less on weaknesses. Learners are different rather than better or worse. There is also a great deal of evidence that failure to learn may often be a matter of style or strategy rather than intelligence or similar feature of an individual invoked to explain poor performance.

The application of constructivist theories of learning described previously may be able to focus on an individual's strengths and to use these to support learning more effectively. In addition it might be possible to look at how people apply their own particular strategies to learning and learn from this how best to support learning in areas where a necessary strategy is absent.

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

Entwistle on the other hand has identified three major categories of learner style, deep, surface and strategic. The styles are based upon learners' motivations, intentions and related learning strategies. Learning strategies consist of any behavioural or thought pattern that facilitate encoding in such a way that knowledge information and retrieval are enhanced. In this model, motivation, intention, strategy and tactics are explained at these three levels. For example surface motivation may involve completing the course for fear of failure. Deep motivation might include interest and vocational relevance and strategic motivation could involve obtaining high grades and being competitive (Entwistle 1988). Kolb (1984) has developed a system for

describing preferred ways of receiving information. Two dimensions are described in Kolb's system Convergents / Divergers and Assimilators / Accomodators. Kolb focuses very much on learning styles as opposed to cognitive styles.

Riding argues that there are two families of cognitive styles which he displays on a two dimensional surface, Wholist-Analyst forming one dimension and Verbaliser-Imager the other. Over 30 labels have been found in the literature to refer to cognitive styles and related concepts. These have been classified by Riding and Cheema into two principal cognitive styles and a number of learning strategies as shown below.

Cognitive Style Families: These are permanent characteristics of an individual and exist in two orthogonally related families. They are relatively stable or fixed in an individual, and are innate. Two families are described which correspond to Riding's dimensions:.

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

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

Learning Strategies: These are used by an individual in response to specific learning situations and may be changed by an individual due to experience. Many tests and classifications of learning strategies have been developed over the years. For example the following have been used in research and as the basis for the configuration of training for an individual.

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

The whole area of the classification of learning styles and strategies is complex and made more difficult because the usage of the terminology is far from clear and inconsistent. It is not always evident what characteristics the various screening tests are measuring and how far they are based in theory or practice. Riding and Read (1996) for example distinguish between learning style and learning strategy. Learning style is a relatively fixed characteristic of an individual and is seen to be independent of intelligence though it will be likely to affect performance in tasks. Learning strategies will

also affect performance, but are learned in response to particular problems to provide specific solutions.

The practical application of learning styles research to CBT has been investigated by De Diana and van der Heiden (1994) who have looked at electronic study books and individual modes of learning, or learning styles. The Style Initiating Module (SIM) is used at the beginning of the learning process to assess the individual learning style of the learner entering the study book environment. Based on a set of neutrally stated multiple choice questions, the test is designed to set a series of switches, according to the learners preferred style. The output of the SIM could be used to determine the way materials in the electronic book are presented, according to preferred learning style. They present options to relate learning styles and books, using the style initiating module within their application. The key difference between a paper book and an electronic book is seen as the additional cognitive support that could be offered by the electronic book, supported by the use of the SIM. The electronic book may be conceived as an interactive mind tool connected to a multimedia database which uses the styles initiating module to configure presentation of learning material for the individual learner.

The direct application of research into learning styles and multimedia / hypermedia are few. Ayersman (1993) provides a conceptual foundation for the development of hypermedia as an instructional tool for addressing individual learning style differences. The relationship of hypermedia to the following learning theories is examined by Ayersman (Information processing, semantic networks, concept webbing/mapping, frames/scripting and schema theory from Piaget's work; Ayersman 1993). Ayersman found that performance on computer based learning systems was indeed related to learning style. There was a negative effect on learning when styles of presentation and learning were mismatched and a positive effect when they were matched.

It is essential that design and evaluation of multimedia learning applications take into account the individual characteristics of the learner. Individual characteristics of the learner, coupled with measures of performance have been used in the development of knowledge based, 'intelligent' learning systems that take over control of the learning process. What seems more important is the requirement of the learner to take control of their learning, not the computer. The application of constructivist learning theories and the ability to configure learning for the individual, based upon their preferred mode of assimilating information has tremendous potential for the design of multimedia learning systems in the future.

2.5 Computers used in training

Computers have been used in training for many years. The learning environments provided by early systems were not rich in today's terms, but in the context of their time were revolutionary.

The systems described below are referred to as 'training applications'. This is because the emphasis in their design was based very much on ideas about how teaching should take place, not learning. They were intended to teach or train people.

The potential of computers as deliverers of training had long been suspected and a great deal of research has taken place since the 1950s into this application of computers. Patrick (1992) gives four uses of computers in training, namely provision, development, management and research. Early attempts at using computers in training arose from programmed instruction methods, influenced by Skinner's research, described earlier. Later more 'intelligent' tutorial systems were developed that attempted to create varied and responsive learning environments using the increased power of the computer.

The terminology used for computers in training is not straightforward and is used differently in the United States and the UK. A simple operational distinction between Computer Assisted Learning (CAL), Computer Assisted Instruction (CAI), Computer Managed Learning (CML), Computer Based Training (CBT) and Computer Based Learning (CBL) is summarized by Staley (1995). The use of the term CAI in the United States was related to training packages that were largely focused on the subject matter and often involved no more than drill and practice. CAL focuses more on the learner and involves discovery, simulation and games. CMI and CML allow the sequence of learning and instruction to be planned and monitored, including assessment test, record keeping, diagnosis and remedial guidance. In the United Kingdom the term CAL is used very much as the term CAI is used in the United States.

The use of computers in training has been studied since the 1950's. Research has centred on the comparison between systems and their relationship to theories of learning. Some early attempts at creating learning programs were referred to as programmed instruction (PI) or programmed learning (PL). Evaluation of the such behaviourist influenced systems is complicated by the wide diversity of studies undertaken, the time scale of the evaluations and the difficulty in assessing precisely what the systems are being compared with. A review by Hartley looked at 112 studies in programmed instruction, a precursor to CAL (Hartley 1966). Hartley concluded that those undertaking programmed instruction took less time to complete the course than conventional training, had better post test scores on

average, but re-test scores were not significantly better. Hartley cautions that the studies he reviewed were often small scale.

Programmed instruction formalized aspects of course design and led to the development of CAI and related systems. Patrick (1992) states that four features of PI were important in the subsequent development of computer systems for learning.

- The shift from open loop to closed loop training systems (feedback from trainees).
- The definition of training objectives and content and structure of programs.
- The trainee as an active participant and not just a passive recipient of training.
- The development of self contained training packages.

A model for the design of computer assisted instruction (CAI) programs has been developed by Cooley and Glaser. They suggest that:

- The goals of learning are specified in terms of observable student behaviour.
- Initial assessment of students' capabilities be undertaken.
- Educational alternatives suited to the students' initial capabilities are presented and assigned / selected.
- Instruction proceeds as a function of performance, instructional alternatives and competence criteria.
- As instruction proceeds, data is generated for monitoring and improving the instructional system.

(Cooley and Glaser 1969)

The behaviourist influence in the above guidelines is readily apparent. CAI systems include simple drill and practice systems as well as more complex tutorial systems. Suppes and Morningstar describe applications of drill and practice systems in mathematics (Suppes and Morningstar 1969). The system they describe is able to present individual tutorials to learners, determine entry level by administration of a pre-test, assign lessons according to entry level, compile performance records, assign lessons according to progress and level within the program and administer a post test. Suppes and Morningstar concluded from their study of students in California and Mississippi that CAI programs will have 'striking benefits' in environments that are not socially or educationally affluent. Drop out rates were found to be less in some CAI programs as were retention and re-enrollment rates. Early applications of CAI include the PLATO (Programmed Logic and Automated Teaching Operations) system where modifiable graphics and touch panel technology has been used in mathematics, pilot training and recipe development (Hurlock and Slough, 1976). The system had extensive student

data and evaluation data handling capabilities. It had an author language (TUTOR) to assist in development of material. The TICCIT system (Time-shared Interactive Computer Controlled Information Television) was developed in the 1970s in America (Merrill 1988). TICCIT invites the users to plan and design their own program of study and provides user control within a predetermined program structure. Hartley stated that the completion rate of the TICCIT was 16% compared to 50% on conventional maths programs. Post test results however were more than 10% better for TICCIT than those on conventionally taught programs (Hartley 1985a).

McCann reports a remedial math program using the PLATO system (McCann 1975). The use of feedback to reinforce students' performance was preferred by students, though it did not significantly affect performance. The use of more 'intelligent' CAI tutorial systems to deliver training may be contrasted with drill and practice systems. Such systems often have complex rule procedures built in to them that make them more typical of students' interaction with humans than simple rote learning systems (Collins and Adams 1977). The keynote of many such systems is flexible use with real time decisions, branching and differentiated paths available to students depending on performance in the program. Collins and Adams (1977) have compared the use of such a tutorial system with a linear non interactive system derived from programmed instruction systems, which was claimed to be less effective in delivering learning.

The Office of Technology Assessment in the USA states that up to three hundred hours are required to produce one hour of CBI, compared to thirty hours to produce one hour of classroom instruction (The Office of Technology Assessment 1990). Fielden (1977) has looked at the cost effectiveness of CBT, emphasizing the subjectivity and complexity of comparisons. Costing criteria and measures of effectiveness of military CBT systems evaluations have been criticized by Orlansky and String (1979).

Attempts at direct comparison between conventional teaching and learning from computer delivered systems need to be viewed with extreme caution as indeed should generalisations relating production time to training time on the computer. Cost effectiveness is extremely difficult to quantify objectively. Measures of both cost and effectiveness may be difficult to arrive at accurately.

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

'penalized by scorn' and successes are positively reinforced in CAI systems (Singer 1968). Tutors have more time to spend with students (Dossett and Hulvershorn 1983).

Not all the results of studies were positive however. The cost of CAI systems is expensive (Goldstein 1993) although the costs are falling. Some learners prefer to be taught by conventional methods and not by machines (Pattern and Stermer 1969). This is less likely to be the case today as we become more accustomed to using computers.

It is important, if the full potential of new technology is to be realised, that it is integrated into systems that already exist. Integration with existing (traditional) systems may be capable of producing really cost effective use of new technology. Instead of comparing features of new and old systems, one might look to identify effective features of both and determine ways that they could be used together.

The development of new technologies and their integration with three established educational technologies has been studied by De Diana and White (1994). The information highway and the use of Computer Supported Collaborative (or Cooperative Work) (CSCW), Computer Based Learning (CBL) and Electronic Books (EBs) is discussed. The synergy between these is emphasized, especially in the context of a networked environment, with CSCW offering spatial and temporal freedom, CBL offering multiform and intensive support to learning and EBs offering an adaptable and accessible knowledge source.

The potential of the computer for delivering learning, configured for the individual, yet structured according to constructivist theories of learning has been suggested in the previous sections. Early attempts to design applications based on Behaviorist theories of learning and the limitations of these have been described. Rather than compare computer based learning systems with other systems, it is probably better to identify strengths in all systems and look at ways of using the best features to deliver effective learning.

Modern computers have enormous power, even when compared to the large mainframe computers described in the previous section. The potential for using these machines on the desk top or in the classroom to deliver learning is enormous. Multimedia computing is a fairly recent addition to the tools available for the delivery of learning. The use of interactive multimedia to provide realistic simulation, full screen high resolution colour graphics, sound, animation and video provides not only great potential, but also additional challenges in the designer of learning.

The description of constructivist theories of learning as described in the previous sections, involving metacognition and selection of personal learning

strategies, applied in social contexts may be considered by some to be at odds with the concept of computer based multimedia delivered learning. Multimedia learning applications are often conceived as 'stand-alone' systems based on instructivist principles that completely neglect any social context and avoid group interaction. Clearly if computers are to be used to deliver effective learning, then great care must be taken in how such systems are designed and perhaps even more importantly, how they are used.

3.0 Applications of multimedia / hypermedia in learning

The following section defines multimedia and hypermedia and looks briefly at the component media. In the past, there have been attempts to consider learning in terms of properties of the component media of multimedia learning systems. Comparisons between the effect of the various media on learning have proven difficult to perform and interpret. Some of the reasons for this are discussed later in this review. Important guidelines for developing educational multimedia have evolved and are given in the following sections.

3.1 Definition

Multimedia has been defined by several authors. Mathison (1991) and McAteer and Shaw (1994) agree that it implies the combination of databases, text, graphics, animation, sound, video and speech synthesis into interactive computer delivered applications. Mathison(1991) provides definitions of specifications, standards, common terms and applications of multimedia in education. Gayenski (1992) provides a concise summary of common terms used in multimedia and shows the relationship between the media, bandwidth and multimedia applications. The concepts of hypermedia, hypertext and multimedia are explained by Rada (1996) who sees multimedia as synchronized media. Hypertext is text with links and hypermedia is described as multimedia with links. In systems used for learning, interacting with the application may add an extra dimension to what is possible. It is important however, according to Hall that interaction is not merely a button clicking exercise used to navigate passively around information databases (Hall 1994).

3.2 Designing multimedia / hypermedia applications.

This section considers research into the component media that comprise multimedia and their use in the design of learning applications.

3.2.1 Text

The use of text as a medium for the delivery of teaching and learning goes back many years. Text has advantages over many other media in that it represents an efficient way of passing large amounts of information, which

can have a very specific and unambiguous information content if so desired. Pictures may speak a thousand words, but they do allow much interpretation.

There has been much research on the organization and layout of text in presentations. There are several reviews available, Hartley (1985b) and Wright (1977) cover early work in the area of textual presentation.

A set of recommendations was proposed by Wright and colleagues.

- Use common terms and avoid technical words.
- Use words with their common meaning
- Use active rather than passive sense.
- Use short sentences and phrases
- Separate text with headings, spacing etc.
- Use boxes and colour to highlight text.

(Wright et al 1982).

These recommendations are concerned as much with the linguistic content of the text than with its presentation and layout. It has proven difficult to separate out the presentation and content of text in studies.

In textual display it is possible to separate out several factors or variables that are likely to be important in presentation or delivery of text based learning material. These include:

- Text size
- Text colour and background colour
- Text font and case
- Layout and formatting
- Amount of text presented on screen
- Length of line
- Language level of textual material and learner
- User manipulation of text (printing, modifying, scrolling, paging etc.)

Guidelines for the above are given by many authors, for example, Koelers et al (1981), Galitz (1989), Cox and Walker (1993).

There is an assumption that pleasing screen layout will lead to efficient transfer of learning (Clarke 1992).

3.2.2 Images

Technical aspects of image display on computers are covered fully in several texts, for example Hearne and Baker (1986) and Foley et al (1990). Duchastel and Waller looked at images and their effect on text in instructional materials (Duchastel and Waller 1979). They were able to conclude that

most texts are improved by the addition of images. Levie and Lentz (1982) looked at the presentation of images to support text. In general they found that:

- Illustrations not overlapping the textual content of a passage will not improve learning of the text.
- Textual redundancy is important.
- Non illustrated text is not influenced by the presence of illustrated text..
- Illustrations improve understanding of reading.
- Illustrations can be effective substitutes for words.
- Users should be prompted to use illustrations in their reading.
- Illustrations add enjoyment.

(Levie and Lentz 1982). They were also able to show that when spatial information and structural relationships are important, graphics are effective at conveying this.

Bernard looked at the ways that the effectiveness of illustrations in text could be improved by focusing the attention of the user to features of the image (Bernard 1990). Clarke suggests that if the objective of a graphic is to motivate a learner, then an image of photographic quality is better than a line drawing (Clarke 1992).

Images can serve several functions according to Molitor and colleagues (Molitor et al 1989). The functions that may be supported include:

- Representation, can transmit information that is difficult to do with text.
- Organization, provides an overview of the macro structure, important in navigation.
- Interpretation, the use of visual analogies and metaphors.
- Transformation, re-coding of information, providing visual mnemonics.
- Decoration, to beautify the text.

Petre challenges the view that graphical representations are better simply because they are graphical per se. 'Many writers on visual programming write in this way' according to Petre. who argues that there are some types of information that are difficult to express graphically (Petre 1995).

3.2.3 Video and animation

Computer based video differs from animation in that video is created by a camera and animation by a graphics application. Otherwise there are many similarities between them. There are several standards in existence for video and animation on computers. These are described Yagger (1993). Technical details for a range of video file formats and issues related to their delivery are given by Andleigh and Thakrar (1995).

Text animations may add interest but there is evidence that this may disrupt learning, especially for dyslexics (NCET 1994a). The scrolling of large amounts of text should be under user control. McAteer and Shaw state that movement alerts attention. Animations are able to show processes and development in time, such as growth, complex chemical processes and mechanical devices (McAteer and Shaw 1995). Alesandrini and Rigney investigated learning with material presented by animation. They found that learners performed better after presentation of an interactive simulation than after reading text alone (Alesandrini and Rigney 1981).

A major limitation in the use of digital video is the need to dedicate a large amount of the systems' available resources to its display in terms of storage and random access memory (RAM). This limitation has become less important as the power of modern desk top computers has increased and this has led to increased use of the medium in learning application according to McAteer and Shaw (1995). It is important that sequences are kept short in presentations and that users can control the presentation of the video. The use of CD-ROM to distribute video files is held by Staley to be an important factor in the increased use of video (and sound) in multimedia applications (Staley 1995).

The use of video in learning applications has been described by many authors, for example, Wexley and Latham (1981) looked at management training and Allen (1985) has surveyed language applications. Christel looked at recall of information and attitude to computer based video presentations, and was able to show a significant difference in recall performance (Christel 1994). Chu and Schramm were able to show that groups receiving audiovisual presentations performed better than control groups (Chu and Schramm 1967). A study published by the National Council for Educational Technology (NCET 1994b) has looked at the use of Interactive Video in Schools. Pupils enjoyment of the material was thought to depend on the quality of the media presentation and not just the interactiveness of the material. Differences were noted between the effects of on and off computer work, with off computer work encouraging reflective analytical thinking and on computer work encouraging experimentation. Presentations lacking interactivity were found to be disappointing.

3.2.4 Sound

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

McAteer and Shaw (1995) suggest that a major limitation to the use of sound in computer learning applications is that it is ephemeral. In addition to this it

is difficult to control the speed of presentation of audio information, unlike text, which is under the user's control. There is evidence that the use of senses other than vision can increase the amount of information we take in (Broadbent 1958; Hartman 1961 and Travers 1964).

Guidelines for designing user interfaces using sound are given by Cox and Walker (1993). They distinguish between the uses of sound in computer applications, as confirmation, state information, navigational aid, annoyance (they recommend giving users control over sound) and the use of speech in applications. They note that despite our reliance on vision to obtain information, most communication with other humans is predominantly speech based. They recommend that applications should be able to run with sound disabled. Baggett studied the role of temporal overlap in the presentation of audio and other information (Baggett 1984). She found that temporal order of the presentation of sound and film was important in recall of information in the presentation. When auditory components preceded visual components, much of the auditory component was lost. This was attributed to differential formation of dual media associations.

Several authors have looked at the use of sound in learning. Barron and Atkins, for example, noted that there were few guidelines for designers relating to the use of sound in multimedia applications (Barron and Atkins 1994). They were able to show that audio was effective in learning. Earlier work by Barron and Kysilka indicated that there was no significant difference when students were tested for immediate recall between a text based program and a combination text/audio program (Barron and Kysilka 1993). Muraida and Spector were not able to demonstrate differences between treatments for a variety of combinations of text and audio presentations (Muraida and Spector 1992). Nugent found increased learning when pictorial and audio information was presented together, but not with audio and textual information (Nugent 1982). Hartman found that audio and print presented simultaneously was better than either alone, when the textual information therein was redundant (Hartman 1961). Enerson and Tunney found that redundant audio was important in learning (Enerson and Tunney 1984). Alessi and Trollip found that presenting text with full narration impeded learning (Alessi and Trollip 1991). Barton and Dwyer suggested that subjects with high verbal skills do not benefit from the addition of audio information (Barton and Dwyer 1987). Kenworth supports this view, suggesting that poor readers benefit from hearing text presented providing sound and text correspond exactly (Kenworth 1993). Jasper states that there are many contradictions in the research performed in this area, probably due to variable experimental designs and other related factors (Jasper 1991).

3.3 Designing Multimedia and Hypermedia for Learning

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

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

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

Cognitive overhead can result from maintaining several trails at once. Limited capacity of human information processing is the reason for cognitive overhead. Excess orientation, navigation and user-interface adjustment place added strain on the user leading to cognitive overhead. Orientation cues are necessary according to Khan (1995) in order to:

- Identify current position with respect to overall structure.
- Reconstruct path to this position.
- Distinguish options for moving on from this position.

There is a correlation between orientation and comprehension according to Dillon and colleagues. This has been interpreted to show that the readers mental model depends on aspects of content and spatial information (Dillon et

al 1994). Aspects of navigation include direction, moves forward and back, up and down and distance, steps and jumps (Khan 1995).

User interface adjustment relates to re-sizing, moving, closing windows etc. Tiled windows have been shown to lead to higher accuracy and speed by Bly and Rosenberg (Bly and Rosenberg 1986).

Authors might increase cognitive coherence and reduce cognitive overhead by considering the application of the following:

- Use labelled links.
- Indicate equivalence between information units.
- Preserve the context of information units.
- Use higher order information units.
- Visualise document structure.
- Include clues as to current location, path here and path onwards.
- Provide navigation facilities which cover aspects of direction and distance.
- Use stable screen layout with windows of fixed size and position.

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

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

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

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

4.0 Discussion

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

The application of learning theory to the development of multimedia will produce a new generation of high quality learning applications. The development of this process has included early research into the effectiveness in the delivery of learning of the component media that comprise multimedia. This work has looked very much at the effectiveness of the individual media in the delivery of learning. Other research has centred on comparison between the types of media, text and image for example, and attempts to show the effect on learning of these different media (Reeves 1993). Reeves identifies some problems with this type of approach. The fact that there is a problem is evident from the ambiguous nature of much of the findings according to Reeves. Some of the reasons for this ambiguity include the following:

- The nature of the comparisons, do they compare like with like? Is a good text based package being compared with a poor image centred package? Is a poor classroom teacher being compared with good CBT application?
- The nature of the studies, are they adequately controlled? There are many extraneous variables that need to be controlled. This control is not always apparent in studies.

- The subject, prior skill, expectations, level, intelligence etc. Attempts to control these variables are possibly begging the question.
- The academic area. Differences in the subject matter of presentations is likely to be extremely important in comparative studies.
- The academic level. Often research is based on under graduate or higher level subjects.
- The nationality of the subjects involved. Much early work was based in the USA.
- The period in history. Much work was done in the 1970's before the PC, before colour television.
- The learning environment. This includes the learner and the teacher as well as the classroom or study area.

Rather than compare multimedia with other systems, it is better to find ways of identifying what is good in multimedia systems according to Reeves.

Many authors agree that the application of learning theory to the development of multimedia applications is essential. The move from an instructivist to a constructivist approach is almost universally stressed. The need to found learning in social contexts is emphasized in these theories. Interactive computer based multimedia is well suited to this development as it has the potential to deliver high quality, high powered simulation.

Computers can also hold information about the learner that can lead to the individual configuration of learning for the learner in the form of a student model. Muldner and colleagues describe a student model as a representation of the learner's knowledge in a form that may be used within a computer learning application. It is used in such applications to configure the software specifically for an individual learner. A full and comprehensive student model is extremely complex and impossible to obtain according to Muldner and colleagues. Questions and tests however may be used to find out something about the state of the students knowledge within a domain and this may be represented within the student model. Presentations of the courseware may then be adapted based on the student model. Test scores within courses, pretest and posttest scores may be used to modify the student model and influence subsequent configuration of learning applications (Muldner et al, 1997). The need to configure learning for the individual will be central to the future development of constructivist multimedia learning applications.

Individual configuration of learning applications for individual users will pose many challenges for their evaluation. The evaluation of multimedia and hypermedia applications has been approached by many authors. For

example Dix and colleagues have looked at usability issues (Dix et al 1993). Henderson and colleagues describe the application of four methods of evaluation, questionnaire, logged data and verbal protocol analysis to computer applications. They found that an approach combining several methods was best (Henderson et al 1995). Laws and Barber describe video based methods of evaluation (Laws and Barber 1995) and Yildiz and Atkins criticize the simplistic comparative evaluations of the 1970s where the use of a new media is compared to traditional methods of learning delivery. They provide guidelines for evaluating educational multimedia (Yildiz and Atkins 1993). A challenge for the future will be the application of this understanding to the new problems posed by individually configured multimedia learning applications.

5.0 References

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